OXFORD MANUALS OF FORESTRY

THE ECONOMICS OF FORESTRY

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PREFACE

THIS book is founded on courses of lectures given at the School of Forestry and the Imperial Forestry Institute at Oxford. Since writing should be more concise than lecturing I have condensed my material as far as is possible without sacrificing clarity; and since the subject dealt with is as yet in an elementary stage I have been content to indicate the methods that can usefully be applied and the results that have so far been obtained, and have refrained from labouring the conclusions that might be drawn from them.

The study of Forest Economics necessarily entails a good deal of mathematical calculation. Such calculations involve two processes, firstly the construction of formulae, and secondly the determination of values of costs and income which can be inserted in the formulae. The formulae can be deduced from simple mathematical principles and, with a little ingenuity, their number can be multiplied to an almost unlimited extent; but the determination of figures to put in these formulae demands patient and systematic costings, and it is in respect of such data that the subject is deficient. Those who have had to teach Forest Economics have propounded general principles, and beyond this have had little more than formulae to present to their pupils, so that the subject has come to be regarded more as a mathematical exercise than a branch of forestry.

Before we can break away from this tradition much more detailed analyses of costs and receipts will be necessary. In this book, however, I have concentrated on the practical problems of forestry, using such data as are available, and have introduced formulae only as they are required for the solution of these problems. This treatment leads to omissions. For instance, I have said nothing about the selection system of forest management because I have been unable to find any reliable data on which to estimate profitableness under this system; and many of the classical formulae of 'forest valuation' have been omitted. But a concentrated attack on those problems which allow of solution is preferable to a diffusion of energy in a premature attempt to cover the whole subject.

The book is chiefly devoted to a discussion of timber resources and the economics of cultivation. The economics of the transport and conversion of timber, a subject which is almost a clear field for inquiry, has been only lightly touched upon.

Management and policy should not be governed solely by economic considerations. Nevertheless, to lay down a forest policy without first studying the total costs of producing timber and the prices that may be obtained for it is a reprehensible extravagance. The financial success of an industrial undertaking can only be judged when the process of production is completed; and, since the period between sowing and reaping in forestry is generally longer than the working life of a man, foresters escape the gruelling test of profit-making to which other cultivators are subjected. For this reason many foresters of established reputation have been able to show a disregard for the major considerations of economics that would have reduced them to bankruptcy in any other industry. Bearing this in mind I have attempted to present the economics of forestry in a form which may be useful in deciding questions of forest management and in determining forest policy.

I am indebted to Professor R. S. Troup who criticized my manuscript and to Professor D. H. Macgregor who read the proofs of chapters iv, v, and vi, and made many valuable suggestions. My wife has assisted me throughout, and her critical acumen has been unfailingly applied to the craftsmanship of the book.

W. E. H.

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INTRODUCTION

'Personally, I believe that few mental attitudes are more pernicious, and in the end more disastrous, than those which would uphold sound practice by denying sound principles because some thinkers make unsound application of those principles. At any rate, in scientific study there is no choice but to find and state the unvarnished truth.'—IRVING FISHER, *Purchasing Power of Money*, p. 15.

IT has frequently been observed that, if men were actuated purely by a desire for financial gain, the forests of the world would gradually be cut down and very little effort would be made to replace them. The period of production of a forest crop is so long that money spent on regeneration and after care yields a low rate of interest, and the economic man can generally find a more profitable use for his capital. Except in so far as state control has been exercised for their preservation the history of the world's forests has been a story of devastation, formerly with the object of clearing land for agriculture and latterly with the inducement of realizing the commercial value of the timber. Only in a few European countries and in India has any consistent policy of forest management been followed for any considerable period, and in each of these countries the government has been responsible for adopting efficient forest methods.[1]

The fact that methods of forest management have been evolved under a system of state ownership has allowed foresters to adopt a less strictly financial view than the managers of other industries. They have been guided by social rather than economic requirements, and their policy has been determined not by a desire for gain but by a fear that the welfare of peoples might be jeopardized by a failure in the supply of forest products, especially firewood, and by a belief that land which is unsuitable for other purposes should be made as productive as possible. The case for forestry has been based on the objective of general human welfare rather than financial gain, and emphasis has been placed on the indirect benefits which forest maintenance often confers, such as the fixing of mountain slopes and shifting sand, and the regularization of the flow of rivers.

Foresters all over the world realize that the case for forestry is a very strong one, and only those who are ignorant of the disastrous

[1] There are a few striking exceptions to this generalization. On some of the very large estates of eastern Europe, especially in Czechoslovakia, owners have been sufficiently wealthy and far-sighted to take the view of governments. Many landowners in Britain and elsewhere have made sporadic attempts to manage their forests on a principle of sustained yield.

consequences that have followed widespread devastation in many lands can fail to acknowledge the importance of maintaining an adequate area of forest in any country. The direct money returns from forestry do not give a fair picture of the benefits that are derived from the industry, and, consequently, the financial side of forestry has been frequently neglected. Those who work out the rates of interest on capital which can be earned in forestry, and publish their results, are generally unpopular because they tend to make forestry appear unprofitable, and this may adversely influence the general public which has ultimately to decide on the extent to which forestry shall be publicly maintained. For this reason forest economists have generally been denied any important share in the determination of forest policy, and the study of economics has been treated with respect only so long as it remained academic.

There is another factor which, for many years, has retarded advance in the science of forest economics. In forestry the productive period of the commodity is longer than in any other industry. Timber takes anything up to five hundred years to produce; and as the economic theory of production is founded on industries which can produce commodities in a few years at most, such theory was not readily applicable to forest conditions. Forest economists had, therefore, to develop an economic theory of their own, and very real difficulties were encountered in doing this. Very diverse views have been expressed, and as economists could not speak with a single voice opportunities were afforded for their opponents to accept, and cling to, just those economic beliefs which supported the methods they practised. The most flagrant example of this is the so-called 'forest rent theory' which is adopted in support of the long rotations practised in Germany. These long rotations involve a very large wastage in national wealth, but for silvicultural reasons they are popular, and the indefensible theory of 'forest rent' has been maintained in order to lend them a semblance of economic support. As this theory is still maintained, even by some forest economists of world-wide repute, chapter xi has been devoted to its analysis.

The twentieth century, and particularly the period since the war, has seen the birth of a new and much more practical interest in forest economics. Wages have risen everywhere and in many countries, notably in Germany, the prices of standing timber have not risen proportionately with other prices, so that profits have decreased. Also the shortage of capital and the high rates of interest which have to be paid on loans has directed public criticism towards

a system of forest management which retains large amounts of realizable wealth in forests which produce a relatively small income. Interest in forest economics has also been aroused through the adoption of more active forest policies in America and the British Dominions, where forestry is freer from both the support and the trammels of tradition and is regarded from a commercial rather than a social standpoint.

These changes have given rise to a far more reasonable attitude towards forest economics. It is now more widely realized that, although the case for forestry cannot often be based on purely financial grounds, once it has been decided to make forests or to maintain forests in good bearing condition, very careful attention must be paid to financial considerations. Though the rate of interest which can be earned on capital may be low, no effort must be spared to make that rate as high as possible so long as due regard is paid to the other objects which the management has in view.

Analysis of the finances of forest undertakings discloses the fact that profitableness varies within very wide limits from place to place and system to system. The factors which chiefly affect profitableness are (*a*) soil and climate, (*b*) species, (*c*) cost of land and management, and (*d*) markets. Britain is favoured above other countries in the northern hemisphere in possessing a climate admirably adapted to the growth of a wide range of conifers and a very large home market with good prices. Also, our range of indigenous trees is very restricted and there is little or no opposition to the use of exotic species, which greatly widens the opportunities for selection. Most foresters want to plant those species which are likely to prove most profitable on the areas under their control, and this creates a demand for very careful analyses of the costs of production of various kinds of timber. It is realized that cheap land, cheap planting, and cheap management may not be economic, and the object of management is to obtain the best relationship between the cost of production and the selling price.

To economists it must appear anomalous that any industry which produces one of our basic raw materials can be conducted over a prolonged period while failing to yield returns commensurate with those obtained from other investments. If the growing of timber were left to private enterprise, curtailment in supplies might be expected to enhance the price until cultivation became profitable, and the ordinary laws of supply and demand might be expected to operate in this manner if no state interference occurred.

In actual practice cultivation under state auspices has not as yet

been sufficient to influence the world price of timber, and the difficulty in making forestry pay is due entirely to the fact that in the world markets cultivated timber has to compete with wild timber which has cost nothing to grow. So long as there exists sufficient wild timber to meet the requirements of the world's population the price of timber will be dominated by those supplies, and cultivated timber will only have the advantage that it is generally grown in fairly accessible places.

The timber market recognizes two great classes of timber: hardwoods which are the product of broad-leaved trees or angiosperms, and softwoods which are obtained from conifers. Owing to the immense stores of hardwoods in the tropics it does not appear that there can be any failure in the supply of these timbers as a class for many generations, though there may be a shortage of certain species and, owing to the high cost of extraction, hardwoods are generally more expensive than softwoods. There are definite reasons for fearing, however, that the supply of softwoods may become inadequate within a few decades, in which case prices may be expected to rise to such an extent that cultivation becomes really profitable. Incidentally, one of the strongest arguments for state forestry is that, if a shortage occurred, it would take many years to grow fresh supplies; and it is the business of governments to see that no prolonged failure in the supply of a basic raw material occurs.

It is clear from the foregoing that no broad view of forest economics can be obtained without a study of the world supply and consumption of timber and price movements. Consequently the first part of this volume is devoted to these subjects and, though no definite solution of the problems involved can at present be given, an endeavour has been made to present the available and relevant information in a concise form.

The foundations of the general theory of forest economics were laid in Germany and, among others, the names of Heyer, Pressler, Martin, and Endres are well known to foresters throughout the world. These writers maintained a distinction between *forest valuation* (Forstwertrechnung) and *forest statics* (Forststatik); the former branch of the subject dealt with the valuation, by means of formulae, of forest land, immature crops and forests in general; the latter with the relative profitableness of various systems of forest management. The work was mostly of an academic nature, and dealt with general principles rather than practical problems, but it has formed the basis on which most subsequent advances have been built, and has provided methods by which practical questions can be tackled.

This is true principally of forest statics, as the formal mathematical methods of valuation have given results which are at variance with practical experience, and theoretical values which have no relation to market prices are of little use.

When we look at the older text-books of forest valuation and statics we find them filled with repellent formulae which no one appeared to use. Examples were generally drawn from imaginary plantations and not from actual operations, and the science appeared rather as an academic exercise for forest students than as a guide to industrial forestry. Since the war, however, forest economists have been active in applying economic tests to practice, which has necessitated a careful study of costs and prices under various conditions of management and an assessment of the comparative profitableness of various systems. These tests are as yet rather tentative; but they are indicative of the influence which the study of economics may exert on forest practice.

An important result of the more practical trend of forest economics has been the discarding of the bulk of the formulae which filled the earlier text-books. When a subject such as this has become overloaded with formulae an emetic of some sort is necessary, and the principle adopted in this book is that no formulae shall be included which are not employed in actual computations. On this principle many of the historic formulae are omitted, but the omission of some formulae which may in the future prove to be useful is considered as a lesser evil than the inclusion of numerous formulae which are not used.

Unfortunately, there is in forestry no quick and direct method of estimating profitableness. In a forest which is operated on a system of sustained yield the income and expenditure account should regularly show a balance and in this sense a profit should always be secured. But the amount of profit must be considered in relation to the amount of capital which yields it, and the amount of capital invested in the forest may be estimated either from the realizable value of the land and the timber which it carries or from the amount of money which has been spent in producing and maintaining the forest.

Alternatively, a forest may be looked upon as a collection of separate stands of different species and ages, and the cost of each stand may be computed from its initiation onwards and the value of the crop which it yields may be expressed in terms of this cost. This method applies equally to single plantations which are not a part of a larger forest.

Of these two methods the second has given far more useful information to forest economists than the first. Just as agricultural economists can learn more from the costings of individual fields than from the returns from a whole farm, so forest economists can learn more from the expenditure and income from small areas than from a whole forest. But, whereas the profitableness of a method of farming may be tested on the results of a few years, the rotation in forestry is so long that a lifetime is often insufficient for this purpose. And, even when figures are obtainable of the costs and returns of certain areas over a whole rotation, the value of such figures is limited by the fact that during this period the purchasing power of money will have changed, and the methods employed at the beginning of the rotation may be very different from those now in use. Consequently, computations in forest economics are usually based on the present cost of each operation that is necessary, and the returns which are at present obtained from the type of stand to which the costs refer. This method is a little unreal, but it cannot be avoided.

As a criterion of profitableness it has been usual to estimate either the rent on the land to which the returns from forest cultivation are equivalent or the rate of compound interest which such returns represent on the capital invested. In this book a new method has been advanced. An attempt has been made to estimate the actual cost of production per cubic foot of timber trees of various species and sizes when certain rates of interest are charged on capital. When sufficient experience has been gained this method may prove to be the most useful yet adopted, and it certainly gives a very clear picture to the grower of which species and which sizes are likely to prove most profitable. But the method is too new to have been employed very widely even in this volume.

PART I

TIMBER SUPPLY, CONSUMPTION AND PRICE

I

TIMBER SUPPLY AND CONSUMPTION

The nature of timber resources: store and increment: gross and net increment: the relation of permissible felling to gross and net increment: forest management and devastation. Example from the U.S.A. The accuracy of statistics of area, volume, increment, and consumption: merchantable and unmerchantable timber: Zon and Sparhawk's book: confusion between gross increment and net increment. Some world statistics: use of word 'billion'. The forestry position in Europe: discrepancy between Zon and Sparhawk's and Fraser Story's estimates. The world's imports and exports. Finland: Sweden: Canada: United States of America.

The nature of timber resources: store and increment. When we speak of the timber resources of the world we may mean either of two things. We may mean the amount of timber standing in the world at the present time, which is a static conception; or we may mean the crop that is annually grown, which can be removed annually without depleting the forests; this is a dynamic conception. We may distinguish the first as the timber *store*, the second as the timber *increment*.

Again, two forms of timber increment must be distinguished. The *gross increment* is the total growth of the living trees in an area of forest during a given period—generally a year. The gross increment may be high in a virgin forest, and is generally computed by stem analyses of the growing trees. The *net increment* is the gross increment less the loss through decay, fire, and all agencies of destruction other than human utilization.

On a large area of virgin forest the volume of timber remains fairly constant from decade to decade. Many trees die and their timber rots, but young trees are always growing and the two processes, growth and decay, in general balance each other. The gross increment may, therefore, be considerable, but the net increment is nil. If an area of forest is devastated by fire or a serious epidemic disease the loss during the year may exceed the growth and the net increment may be negative; but such catastrophes are generally followed by periods of renewed growth, during which the loss by decay is much less than usual, and during such periods there is a positive net increment. Thus, for virgin forest as a whole, the net increment is nil.

A continuous positive net increment only becomes possible when men utilize the timber from the forest. For human utilization timber, which otherwise would ultimately have rotted, is removed from the forest and this reduces the amount lost through rot. It follows that human utilization increases net increment and net increment cannot reach its maximum until all the forests are being utilized.

When lumbering operations are instituted in a virgin forest the utilization is bound to exceed the net increment, because the net increment is nil. What is important, if the productivity of the forest is to be maintained, is that, after felling, regeneration should be secured and protected; and it is only in forests that have already been cut over that the net increment forms a guide to the amount of timber which may be annually removed without depleting the forest.

As the net increment fails to provide a test of the volume of timber which may justifiably be removed each year from a virgin forest, we must examine the possibility of using estimates of gross increment for this purpose. If all timber could be used before rot set in and if fire could be prevented, then the net increment would become equal to the gross increment, and no harm could be done by removing each year a volume equal to the gross increment. Under good management the loss by fire and decay may be reduced to about 20 per cent. of the gross increment, and under such circumstances 80 per cent. of the gross increment may be annually utilized without prejudice to future supplies. But, again in this case, the most important consideration is the treatment to which the forest is subjected after felling. The gross increment of virgin forest is not generally the maximum of which the land is capable; too much space is taken up by mature and over-mature trees, and the young trees have too keen a struggle for light and moisture. Efficient management after felling should, therefore, increase the gross increment of the area. Further, when the whole area has been cut over and the complete forest is under management the standing volume of timber may justifiably be less than was present in the virgin forest. Thus, under ideal management, the cut in a virgin forest may from the first somewhat exceed the gross increment, and skilful treatment may increase the gross increment so that the cut can be continuously maintained. This is the principle on which Sweden and Finland are at present operating. It appears, on the other hand, that the yield in the state forests of Germany, France, and Switzerland has now reached a state of equilibrium.

What generally happens is very different from this. The most valuable species and the straightest trees are removed, so that worthless trees grow and cover the ground or colonize open spaces with inferior progeny. Under exposure to the sun's heat the soil deteriorates or erosion washes away the soil altogether. If the land has become settled with people, the villagers take for firewood the young trees which might have grown to re-form the forest. In such ways the forest gradually becomes reduced to scrub with no effective increment, and the result is a form of devastation which is common throughout the world. The extensive forests of southern Italy, Sicily, and the Balkans have mostly been destroyed in this way and, even in Britain, a very large part of our remaining woodland has been rendered worthless in this manner.

In new countries devastation may be even more rapid. Areas of virgin forest are looked upon by lumberers as a mine from which timber has to be extracted. No care is taken either to secure regeneration or to protect it if it appears. The best timber is taken and the remainder, even the young poles which might eventually have restocked the forest, is damaged and broken. The debris left on the ground is highly inflammable and, once alight, it not only burns itself but sets fire to the surrounding uncut forest. A single fire may be followed by regeneration but, too frequently, the young growth is wiped out by further fires, the humus in the soil is destroyed and the fertility of the land can only be restored after decades or centuries.

Example from the U.S.A. In America depletion has taken place very rapidly, and the following notes extracted from the 'Capper Report'[1] give a vivid picture of the manner in which it has occurred.

In New England the most valuable original timber was white pine (*Pinus strobus*), and down to 1840 this was practically the only timber cut. It was used not only for houses but for shipbuilding, which became an important industry. By 1870 the original white pine was practically exhausted, and spruce had largely taken its place, but by 1880 the second growth of white pine had become an important source of timber, and yielded 200 to 300 million b.f.[2] per annum. With the extensive use of low-grade pine for boxes and matches this

[1] 'Timber Depletion, Lumber Prices, Lumber Exports and Concentration of Timber Ownership', U.S. Forest Service, 1920.

[2] Board feet. This unit is equivalent to a board 1 foot square and 1 inch thick. Standing timber is measured in board feet according to the volume of *sawn* timber it will yield.

later increased to 600 million b.f. With the introduction of the paper industry timber which was previously too small or too poor for lumbering acquired a value and the total lumber cut rose to a maximum of 3,170 million b.f. in 1907. From then onwards the cut fell rapidly and had dropped to 1,400 million b.f. in 1918. During this period the original 39 million acres of virgin forest has been reduced to 24·7 million acres, and of this only 44 per cent. is producing timber fit for sawing or pulp.

In the Lake States lumbering began about 1835, and owing to the enormous quantities of white pine in this region it became the principal timber producing area in the U.S.A. before 1870, and it held this lead until superseded by the southern pine region between 1900 and 1910. In 1892 production rose to 8,900 million b.f., but by 1918 it had fallen to 3,220 million b.f., mostly of inferior timber. 'The virginal forests occupied practically all the land area of Michigan, Wisconsin, and the part of Minnesota not naturally prairie—a total forested area of approximately 112 million acres. Lumbering and the clearing of land for cultivation have reduced the merchantable forest cover to little, if any, more than 24 million acres, about 58 per cent. in farm wood lots of relatively small timber, commonly second growth, and 42 per cent. in commercial timber tracts, in many cases already culled of their choicest trees. A very large part of the once heavily timbered land, about 20 million acres, is now fire-swept and a devastated sand plain and swamp, much of it with little or no promise of reproduction.'

The great development of the southern yellow, or pitch, pine industry began in the early nineties and reached its peak in 1909 when it produced nearly half the whole country's cut of conifers. It still provided 35 per cent. of the entire cut in 1920 and 'will remain an important factor for at least the next 10 or 15 years' (written in 1920). About four-fifths of the timber has been cut.

The Pacific Coast States at present hold the lead in timber production. The cut has rapidly increased in recent years, growing from 2,900 million b.f. in 1899 to 8,590 million b.f. in 1918. The principal species is Oregon pine (Douglas fir) of which very large amounts still remain. It is anticipated that logging in this area will increase much further with the falling off in production of pitch pine.

Finally the Rocky Mountain region, owing to its inacessibility, has been little exploited except for local needs. The greater part of this timber will remain till higher prices justify its extraction.

The rapid movement of the timber industry in America, first from

the east coast to the Lake States, then to the south, and finally to the west forms one of the most impressive chapters in the history of the forest industry. With the exhaustion of accessible virgin forest America will become dependent on second growth and, in so far as this is inadequate, on imports. It appears probable that timber will in future be imported to America from Europe in large quantities.

The accuracy of statistics of area, volume, increment, and consumption. Reliable forest statistics can at present only be obtained from a few countries and, in general, the more highly developed the forest management of a country the more reliable will the statistics of that country be. The figures quoted for more backward countries are little more than guesses and, consequently, very little confidence can be placed in statistics advanced for the world as a whole.

The *area* of forest in any country may be computed from maps or from forest surveys. Where accurate maps are obtainable, as in Britain and Germany, the map method is by far the most reliable, but where accurate maps do not exist, as, for instance, in Finland, a very fair idea of the forest area may be obtained from line surveys by which the proportion of forest to the total area is computed. In Finland and Sweden this method has been applied with great success. In little known countries such as Siberia and Brazil, both of which contain a large proportion of forest, the area of forest can only be computed from rough maps drawn from the accounts of explorers, and such statistics are, of course, very unreliable. The reliability of these figures is further decreased by including as forest large tracts of scrub growth or bare land which carries very little timber.

The *volume* of timber standing in the forests is less accurately known than the area. Even in Germany, where the state forests and communal forests comprise about 48 per cent. of the whole, and these forests are very intensively managed, it has been admitted that the error may be as high as 17 per cent. The line survey method, as adopted in Finland, gives very fairly accurate results, especially when a very large number of plots is measured, and it is probable that the Finnish figures for volume are more reliable than any others. No figures are generally advanced for the total standing volume of timber in the world or separate continents, and only for individual countries can estimates be quoted.

When timber volumes are quoted a distinction is often made between *merchantable* and *unmerchantable* timber. Merchantable timber is, strictly speaking, timber which could be cut to-day at a profit, that is to say, the present price of the converted timber

would be sufficient to pay for felling, extraction, and conversion, and perhaps, but not necessarily, leave something over for stumpage (i.e. standing value). The distinction is very difficult to draw in practice since in any area the more valuable species may be merchantable and the less valuable not, the larger timber may be merchantable and the smaller not. Also the timber near a river, or other medium of extraction, may be marketable while timber a mile away may not be, and in a year of good prices timber may be marketable which is unmarketable in a year of bad prices. Ideally, however, the distinction exists and it may be applied in a general way to large areas. Thus most of the timber in Siberia and much of that in the Rocky Mountains is at present unmerchantable and will not become merchantable until prices have shown a very considerable advance.

The frequency with which statistics of the total *increment* of countries, continents, and even the world, are quoted suggests that the increment is better known than the standing volume. This, however, is far from being the case, and credence which is attached to increment figures must be ascribed more to the need for information than its attainment. It is a commonplace of forest policy that cut should not exceed increment and that such excess, if continued, must lead to devastation and reduction in supplies. Thus propaganda for forest management is generally based on the belief that cut actually does exceed increment in particular countries, and propagandists need to quote figures to substantiate their contention.

Increment can only be ascertained by sample plot measurements, which may be repeated, so that the actual increment in a given time is measured, or may be made once and the increment assessed by some form of stem analysis. Such measurements are laborious and expensive, and in no country in the world have successive measurements been made in conjunction with any accepted system of percentage forest survey. In making the Finnish survey increment was calculated from stem analyses in a very large number of plots, and this is probably the most satisfactory assessment that has yet been made. In the German state forests, in which intensive management has been practised for very many years, no collected increment figures are available and estimates are based on production, i.e. the volume annually cut, since it is assumed[1] that under German conditions the two must be approximately equal. It should be noted, however, that German state forests are managed so conservatively that increment in many places continues in excess of felling, with the result that some of the forests are becoming too heavily stocked.

[1] e.g. by Zon and Sparhawk.

Examples which show the difficulty of assessing increment figures may be taken from Zon and Sparhawk's *Forest Resources of the World*.[1] This book is the first attempt at a comprehensive inventory of the forests of the world, and its usefulness is indicated by the constant references to it in this chapter. It is open to question whether the time is yet ripe for such an inventory, but the very attempt is a challenge to each country to collect more accurate statistics about its forest resources; although readers of the present book are warned to accept figures from Zon and Sparhawk with great reserve, these warnings are not an implication on the preparation of a great work but a direct result of the inadequacy of present statistics.

In attempting to assess the increment in various countries in the world Zon and Sparhawk have had to choose between the net increment and the gross increment. The net increment is an expression of the replacement of the timber removed in felling by growth, since the loss through fire and decay is allowed for; and it may appear obvious that the gross increment, since it makes no allowance for natural loss, is a figure of little value. But it has already been shown that in virgin forest the net increment is nil and the gross increment may be taken to represent in some measure the fertility of the forest area. The latter is, therefore, a useful figure when we want to estimate the volume of timber which might be continuously extracted from an area, and it should be noted that the increment estimated in the Finnish forest survey is the gross increment.

Zon and Sparhawk state definitely that their assessment is the net increment, but in practice they have estimated the net increment in some places and the gross increment in others. Thus the net increment for Canada is estimated at 2[2] billion c.f., which is equivalent to about 3 c.f. per acre if spread over the whole forest, including virgin forest. For European Russia, on the other hand, the net annual growth is estimated at 35 c.f. per acre,[3] whereas the consumption only represents 20 c.f. per acre. If this were true the standing volume in Russia would be increasing at a rate of 15 c.f. per acre, which is contrary to all belief. Actually Zon and Sparhawk have in this case recorded the estimated gross increment. The confusion between net increment and gross increment is, therefore, a very important source of discrepancies between the estimates of

[1] Raphael Zon and William N. Sparhawk, *Forest Resources of the World*. New York, 1923, 2 vols.

[2] For some reason, which is not apparent, the annual growth is assessed at 0 on page 40 of vol. i.

[3] Vol. i, p. 290—on p. 38 it is estimated at 28·9 c.f.

different authors, and in any estimates it must be very clearly stated which increment is meant.

Only in a very few countries, viz. those with progressive policies, can the net increment exceed the utilization, and in the world as a whole, until forest production becomes stabilized, the utilization must exceed net increment. Thus an excess of cut over net increment should not, in itself, be regarded as a cause for alarm. Further, the growing stock in virgin forest is often greater than that on the same area when put under forest management, so that even under conservative management the utilization may *for a time* be greater than the gross increment.

Estimates of *production* and *consumption* are generally divided into saw timber, pulpwood, and firewood, the last class including many minor uses such as fencing. The production of saw timber can generally be ascertained to a relative exactness since most mills keep records of the amount of wood sawn, but, since the output of sawn timber is not generally more than half the volume of the round timber used to produce it, and since most countries have methods of measuring round timber for sale which give not the true volume but something considerably less, care has to be exercised in converting all figures to a common measure. The true measure under bark in the round is the best common measure for such use.

Estimates of pulpwood are also comparatively reliable, but the volume of timber which is used for firewood can only be guessed very roughly, since in forest areas the inhabitants cut as much wood as they require without keeping records.

Some world statistics. It is clear from the last section that any timber statistics for continents or the world must be accepted with the utmost caution. Nevertheless, it is very interesting to have figures even if they are only accurate to 50 per cent. For no country is the accuracy of figures known to 1 per cent., and consequently two, or at most three, significant figures are sufficient, and any pretended accuracy beyond this is misleading.[1] We have to deal in very large amounts in these statistics and it is impossible to visualize them. The most useful units in British measures are the *million c.f.* and the *billion c.f.* The word billion is used in the American sense of a thousand million (not a million million), and a billion c.f.

[1] The annual growth in China is estimated at 1,972,263,000 c.f. (seven significant figures) and in Europe at 22,586,531,000 c.f. (8 significant figures)! In the latter case we cannot say with any confidence that the growth lies between 20 and 25 billion c.f., so that if we quote the figure at 23 billion c.f. (two significant figures) there is no loss in accuracy.

of timber if stacked in a cube would stand on a base of a thousand feet each way and be a thousand feet high. It is as well to accept the measure as a unit without any attempt at visualizing it.[1]

Table I gives Zon and Sparhawk's estimate of forest area, annual timber production, and annual net increment of the world by continents. The forest area of the world is estimated at 7·5 billion acres, of which nearly half is tropical hardwood, and plays a very small part in meeting human needs. 2·6 billion acres are coniferous,[2] and nearly all this is in the northern hemisphere. The estimated consumption is 56 billion c.f., of which about 50 per cent. is in North America and 30 per cent. in Europe. Rather more than half the consumption is for uses other than saw timber. It is estimated that 75 per cent. of the saw timber and 49 per cent. of the total consumed is coniferous.

Only about 3 billion c.f.[3] are exported from one country to another. This is approximately 6 per cent. of the total consumption, so that about 94 per cent. must be consumed in the country in which it is grown.

The net annual increment of the world's forests is estimated at 38 billion c.f., which is 18 billion c.f. or 32 per cent. less than the consumption. A very large deficiency is shown for North America, and a very considerable balance for Europe. The consumption and growth in these two continents is so important that special sections will be devoted to them.[4]

The forestry position of Europe. According to Zon and Sparhawk the area of European forests is 774 million acres or 10·5 per cent. of the forests of the world. Of this area the coniferous forests comprise 579 million acres, which is 23·5 per cent. of the coniferous forests of the world. The production from the forests is about 30 per cent. of the forest production of the world and represents about 22 c.f. per acre per annum, which is higher than the per acre

[1] It is convenient to remember that the volume of wood imported annually into Britain is about half a billion c.f. In American literature m.b.f. generally stands for a thousand board feet. 12 board feet equal 1 cubic foot of sawn wood, but for conversion purposes it is usual to take 100 board feet as equivalent to 21·9 cubic feet in the round which allows of a wastage of 62 per cent.

[2] Fraser Story (British Empire Forestry Conference, 1928) estimates the area of *accessible* coniferous forest in the world at 880 million acres.

[3] It might be expected that imports and exports could be known to very considerable accuracy, but total pre-war exports were estimated at 3,578 million c.f. and imports at 2,880 million c.f., a discrepancy which suggests the gross inaccuracies that must exist in other statistics.

[4] The position with regard to America is discussed under the headings *Canada* and *U.S.A.* below.

TABLE I. *Area of forest, timber production, and timber increment of the world (after Zon and Sparhawk).*

	Area of Forests. Million acres.				*Annual Production of Timber.*						*Ann. Growth*		*Excess of cut over growth m.c.f.*	*Excess of growth over cut m.c.f.*
	Conifers.	*Temp. h'woods.*	*Trop. h'woods.*	*Total.*	*Saw Timber m.c.f.*	*Per acre c.f.*	*Fire-wood m.c.f.*	*Per acre c.f.*	*Total m.c.f.*	*Per acre c.f.*	*Total m.c.f.*	*Per acre c.f.*		
Europe	579	195	0	774	9,160	11·9	7,843	10·1	17,003	22·0	22,586	29·2	—	5,583
Asia	889	572	635	2,096	1,556	0·8	6,373	3·0	7,929	3·8	7,874	3·8	55	—
Africa	7	17	773	797	62	0·08	655	0·82	717	0·9	989	1·2	—	272
Australia-Oceania	15	15	253	283	93	0·33	182	0·64	275	0·97	472	1·70	—	197
North America	1,046	290	108	1,444	14,986	10·4	12,821	8·9	27,807	19·3	4,459	3·1	23,348	—
South America	109	115	1,869	2,093	259	0·12	2,233	1·07	2,492	1·2	1,654	0.8	838	—
Total	2,645	1,204	3,638	7,487	26,116	3·5	30,107	4·0	56,223	7·5	38,034	5·1	24,241	6,052

production of any other continent. Owing, however, to comparatively efficient management there is less devastation in Europe than elsewhere.

There is considerable diversity of opinion as to whether Europe is cutting more than her increment and, whereas Zon and Sparhawk estimate an excess of net increment over cut of 5·5 billion c.f., Fraser Story,[1] after an independent inquiry, arrived at the conclusion that for *coniferous timber alone* there was an excess of 2·3[2] billion c.f. of consumption over increment. This is equivalent to a difference of 7·8 billion c.f. (46 per cent. of the timber production of Europe) and, though the two estimates are not strictly comparable, testifies to the unreliability of statistics. The discrepancy is mainly due to views adopted by the authors with regard to Russia. Zon and Sparhawk credit Russia with an excess of net growth over cut of 5·7 billion c.f., whereas Fraser Story estimates a debit balance of 1·6 billion c.f. If Zon and Sparhawk's estimate were true the growing stock of Russia would be increasing by 5·7 billion c.f. each year, a state of affairs which certainly does not exist. Thus Fraser Story's estimate is likely to be nearer the true relationship of *net* increment to production; but if we accept Zon and Sparhawk's figure as representing the gross, and not the net, increment, the latter is instructive in showing that Russia's production might be greatly increased without permanent harm to her forests.

Table II shows the forest areas of the better forested countries of Europe. Endres has made the useful generalization that any country with more than about 80 acres of forest per hundred population should have a surplus of timber for export, and on this basis the exporting countries, in order of their *per capita area* of forests should be Finland, Sweden, Norway, Russia, Rumania, Jugoslavia, Poland, Czechoslovakia. It will be seen from Table III that as regards the first two countries this order agrees with the order of countries arranged according to their export of sawn coniferous timber. But the actual exports must also depend on the size of the country, its position and social development. Further, if northern Russia were scheduled independently of the rest of the country its forest area per 100 inhabitants would prove to be higher than that of Finland. This, together with the enormous area of these north Russian forests, indicates that Russia must become the principal exporting country of the future.

[1] *Empire Forestry Journal*, 1923, ii. 218.

[2] The oft quoted deficit of 3,361 million c.f. was arrived at through a mathematical oversight.

TABLE II. *Forest areas in Europe (after Zon and Sparhawk).*

Country.	*Forest Area.*			*Ratio of forest to total land area. Per cent.*	*Forest area per 100 inhabitants. acres.*
	Total million acres.	*Conifers million acres.*	*Hardwoods million acres.*		
Russia (excluding Caucasus)	440[1]	387	53	39	440
Sweden	56	49	7	55	960
Finland	49	43	6	60	1,470
Germany	31	21	10	24	50
France (including Alsace-Loraine)	26	5	21	19	60
Poland	22	13	9	23	90
Rumania	22	7	15	28	120
Jugoslavia	17	4	13	25	120
Norway	17	13	4	21	650
Spain	17	4	13	14	80
Italy	14	1	13	18	40
Czechoslovakia	12	7	5	34	90
Other countries	51	25	26	—	—
Total	774	579	195	31	170

The World's imports and exports, and the principal exporting countries. The total world's imports and exports are about 3 billion c.f. Of this amount the most important item is sawn softwoods, and it is in this item that the fear of shortage is most definitely expressed. Table III shows the exports from the principal supplying countries in the years 1927 and 1913, and the outlook for the future can best be examined through a study of the conditions in these countries and the probable future demands of importing countries. The question of future demand is considered in Chapter II, but the conditions in exporting countries are briefly dealt with in the following paragraphs.

FINLAND. Not only does Finland contain a higher proportion of forest than any other country in Europe but, owing to the enlightened administration, which commenced before the war and has had much freer play since the Finnish emancipation in 1918, a very large amount of information is available about her forests. A line survey was carried out in 1921–4, the results of which were pub-

[1] According to Endres, *Forstpolitik*, the pre-war forest area of Russia, without Finland and the Caucasus, and excluding swamp and water, was 400 million acres. It must now be considerably less.

lished by Y. Ilvessalo in 1927.[1] For the purpose of forest statistics the northern half of Finland (the province of Oulu) was distinguished from the southern half, and productive forest was distinguished from forest of poor growth, the latter being composed mainly of the poorer swamps, rocky ground, and fjelds.

TABLE III. *Sawn softwood exports*, 1927 *and* 1913.[2]

	1927.			1913.	
	Million[3] *c.f.*	*Per cent.*		*Million*[3] *c.f.*	*Per cent.*
Finland . . .	211	19		147	15
Sweden . . .	180	16		195	20
Canada . . .	157	14		120	12
U.S.A. . . .	118	11		163	16
Poland . . .	109	10			
Soviet Russia . .	73	6	Russia	238	24
Latvia	26	2			
Estonia . . .	12	1			
Austria . . .	70	6			
Czechoslovakia . .	44	4	Austria Hungary	90	9
Jugoslavia . . .	37	3			
Rumania . . .	70	6		9	1
Norway . . .	16	2		28	3
	1,123	100		990	100

The whole country has nearly 50 million acres of productive forest and 13 million acres of forest land of poor growth. The gross increment is estimated at 1,560 billion c.f., of which 1,500 billion c.f. occurs in the productive forest, and the utilization is nearly as great as the gross increment. As, however, a considerable area of the forest is unmerchantable the utilization in merchantable areas is somewhat greater than the increment in those areas. The present rate of utilization can be continued indefinitely if the price of timber rises sufficiently to make extraction from the more remote parts of Finland profitable. All felled areas are now regenerated, and by the good management now enforced the increment should rise considerably.

Volume increment is more than three times as great in the southern as in the northern half of Finland, and consequently forest

[1] *Communicationes ex instituto quaestionum forestalium Finlandiae editae*, 11. See also Hiley, *Forest Industry of Finland*. Oxf. For. Mem., No 8, 1828.

[2] Converted from a report by J. L. Elkman translated in *Timber Trades Journal*, 5 May 1928.

[3] It takes nearly 2 c.f. of timber in the round (true measure) to make 1 c.f. of sawn timber.

TABLE IV. *Area of forest, standing volume, and increment in Finland.*

	Productive Forest.					*Forest land of poor growth.*				
	Area million acres.	*Standing Volume*		*Incr. per acre. c.f.*	*Total gross increment b.c.f.*	*Area million acres.*	*Standing Volume*		*Incr. per acre c.f.*	*Total gross increment b.c.f.*
		total b.c.f.	*per acre. c.f.*				*total b.c.f.*	*per acre c.f.*		
South Finland . .	27·8	34·7	1,250	42·7	1,190	4·3	1·5	350	7·4	32
North Finland . .	21·9	19·1	870	14·1	310	8·3	2·0	240	3·4	28
Whole Country . .	49·7	53·8	1,080	30·4	1,500	12·6	3·5	280	5·0	60

Average volume per acre, 920 c.f.

management is far more profitable in the south. The forests of the north, however, contain trees of great age (up to 500 years and possibly more) and, on the average, the trees of the north are larger than those of the south.

The timber consumed in providing material for export (sawn and unsawn timber, plywood, pulp, cardboard, paper) is about 600 million c.f. per annum, of which about 60 per cent. is used for manufacturing sawn timber. The home consumption is considerably greater than the export and represents about 260 c.f. per head of population, which is probably the highest *per capita* consumption in the world.

SWEDEN. The area of the productive forest land in Sweden is about 58 million acres, of which about 13 million acres (22 per cent.) is owned by the state. There is in addition an area of 32 million acres of unproductive forest land of which 19 million acres (58 per cent.) is state owned. As in Finland the state forests are principally in the north.

A survey of these forests is being carried out, and, in a preliminary announcement of the results of this survey, the volume of standing timber is estimated at 50·5 billion c.f.[1] This gives an average stand per acre of between 700 and 800 c.f. The annual increment is estimated at about 1,300 million c.f. or 22 c.f. per acre. In the south it rises to 36 c.f. per acre, but in the north-central region it falls to an average of 14 c.f.

The pre-war annual cut in Sweden was estimated in 1919 at 1,565 million c.f. Domestic consumption accounts for 732 million c.f., wood for export 303 million c.f., wood for pulp 323 million c.f., mine timber 199 million c.f., and wood for tar about 7 million c.f.

There is an apparent excess of cut over net increment of 260 million c.f., but fresh areas of virgin forest are continually being made accessible, and when virgin forest is cut the amount felled may legitimately exceed the net increment. Under proper management the increment should be considerably increased, and there is reason to think that the present rate of utilization can be maintained though it cannot be greatly increased.

CANADA.[2] The forests of Canada are estimated at the colossal figure

[1] M. E. Lindeberg, *Statistique de la superficie forestière*, etc. Actes du 1er Congrès Int. de Sylviculture, vol. ii, p. 48. Rome, 1926: Riksskogstaxeringens, Resultat I, II, III, Skogen, 1927, 1928, 1929. See also A. H. Oxholm, *Swedish Forests, Lumber Industry, and Lumber Export Trade*. U. S. A. Dept. of Commerce, Special Agents Series, No. 195, 1921.

[2] Largely taken from R. D. Craig, *Softwood Resources of Canada*, Third British Empire Forestry Conference, 1928.

of 737 million acres, of which 615 million acres is coniferous. They have, however, been very badly handled, and a large part has lost all its valuable timber, either through utilization or fire. Of the coniferous forests 150 million acres is classed as unprofitable or inaccessible, 270 million acres as unmerchantable young growth, and 180 million acres as merchantable and accessible, of which about 130 million acres is mature virgin timber.

Table V, which is calculated from figures estimated by Craig,[1] shows the distribution of timber and the average volume per acre in various parts of Canada. From this table it will be seen that the total

TABLE V. *Forest area and timber stand in Canada.*

	Forest area in million acres.				
	Merchantable.	*Unmerchantable.*	*Total.*	*Standing vol. b.c.f.*	*Vol. per acre, c.f.*
Eastern Provinces	191	311	502	108	218
Prairie Provinces	73	109	182	56	310
British Columbia	32	64	96	82	850
Total	296	484	780	246	316

stand is estimated at about 250 billion c.f. The total coniferous timber of merchantable size is estimated at 177 billion c.f., of which about half is saw timber, and the remainder of smaller dimensions.[2] Craig considers that 49 billion c.f. of saw material plus 53 billion c.f. of smaller sizes are merchantable and accessible at present prices. About 80 per cent. of the saw material is in British Columbia.

It is instructive to compare these statistics with those of Finland where a much more accurate and detailed survey has been carried out. Finland has an average volume per acre of 920 c.f., which is nearly three times the estimated volume for Canada. It is true that few areas in Finland have suffered from the deplorable devastation which is common in the Canadian forests; at the same time the percentage of swamp and poor land is probably quite as high in Finland as in Canada, and Finland has no heavily stocked areas comparable with the better parts of British Columbia where the volume per acre may locally exceed 20,000 c.f. The Canadian methods of exploitation are very wasteful,[3] and it appears likely that some allowance has been made for this in Canadian estimates. It is estimated that the

[1] R. D. Craig, 'Forest Resources of Canada,' *Econ. Geography*, ii, 1926, No. 3.
[2] Craig, 1928.
[3] See Whitford and Craig, *Forests of British Columbia*, Ottawa, 1918, p. 329.

original volume of standing timber was nearly four times the present stand.

The average annual felling in terms of standing timber in Canada is now estimated at 2·7 billion c.f., of which 1·9 billion is coniferous. The hardwoods are mostly used for fuel, only about 13 per cent. being used for other purposes. Of the 1·9 billion c.f. of conifers annually cut, 47 per cent. is used by the lumber industry, 29 per cent. for pulp, 8 per cent. for railway sleepers, and the remainder for fuel, logs exported, posts, poles, &c.

Table VI, which is made up from Craig's papers,[1] shows the gradual increase in the consumption of wood by the lumber and paper industries. The increase is entirely due to the pulp and paper mills, and the output of newsprint in Canada has increased from 1,266,232 tons in 1923 to 2,086,949 tons in 1927, and is much higher than that of any other country.

TABLE VI. *Approximate average annual cut of standing timber by the lumber and pulpwood industries in Canada in million c.f.*

	Lumber Industry.			*Pulp and Paper Industry.*			
	Lumber.	*Shingles.*	*Total.*	*Pulpwood used in Canada.*	*Pulpwood exported.*	*Total.*	*Total Cut.*
1908–12	916	38	954	76	106	182	1,136
1913–17	843	54	897	178	118	296	1,193
1918–22	789	61	850	293	135	428	1,278
1923–26	858	73	931	495	164	659	1,590

Estimates of increment in Canada are very unreliable, but it is generally assumed that growth is insufficient to replace cut. Craig,[2] however, points out that there are still about 330 million acres of accessible coniferous forests which are in a growing condition, which, with an average increment of 10 c.f. per acre, would give a gross increment of 3·3 billion c.f. Allowing 20 per cent. for loss by fire and disease, this still leaves 2·7 billion c.f. of net increment, which is more than the coniferous fellings. This increment includes a very large amount of young growth which will not be ripe for utilization for many decades; nevertheless, to any one who has seen the devastation wrought by fire, especially in the cut-over areas, this estimate of increment must appear rather optimistic.

[1] And from *The Lumber Industry, 1926,* Canada Dominion Bureau of Statistics, Forest Products Branch, Ottawa 1928.

[2] Loc. cit., 1928.

If the total annual depletion is 5 billion c.f.[1] and the area of merchantable timber is 300 million acres, the present depletion would be compensated for by an annual gross increment of 17 c.f. per acre. Observations in Quebec led the writer to believe that few, even of the best areas, had a gross increment of more than 40 c.f., and the average, even of the areas which were restocked, was probably not more than one third of this. Growth in eastern Canada is slower than in southern Finland though the latter is 15° further north; on the other hand, growth in British Columbia is far more rapid than anywhere in Finland. The most important difference between the forests of the two countries is that in Finland felled areas are carefully restocked, whereas in Canada felled areas are generally devastated, and, unless greater care is taken in the future, the easily accessible areas will cease to yield sufficient timber for her forest industries.

United States of America. The original forest area is estimated at 822 million acres, of which about 470 million acres remain, including areas of second growth, inferior timber, and even a good deal that is not restocking. One of the chief causes of loss has been fire, which during the period 1916 to 1923 took toll of 9 million acres annually. The standing volume of timber was estimated in 1923 at 746 billion c.f., of which 260 billion c.f. is too small for saw timber. More than half of this was coniferous, and Douglas fir alone accounted for 150 billion c.f., and the southern pines 85 billion c.f. The gross increment is estimated at 6 billion c.f. of which 1·73 billion c.f. is lost annually by fire, wind, &c., leaving a net increment of about 4,270 million c.f.

The estimate of gross increment is surprisingly small, less than 13 c.f. per acre per annum, which should be compared with over 40 c.f. for south Finland, where neither climate nor soil are in general so favourable to tree growth. Such an estimate fails to convince European foresters,[2] and it can hardly be comparable with the estimates of increment in European countries. As Endres suggests, this low figure may be partly due to the slow growth of the very old virgin forests, and much of the 'second growth' is no doubt very indifferently stocked; but in many parts of the U.S.A., as, for instance, on the west coast, the conditions are extraordinarily favourable to the growth of conifers and, with the fast growing species that abound there, stocking which is far from ideal should give increments of 100 c.f. per acre or more.

[1] This estimate, which is quoted from Zon and Sparhawk, allows of an annual loss of nearly 2½ billion c.f. through fire.

[2] Endres, *Forstpolitik*, 1922, p. 764.

The estimated annual cut for the period 1909–19 was 24·3 billion c.f., of which 11·5 billion c.f. was hardwoods and 12·8 billion c.f. coniferous. If the above estimate for net increment of 4·3 billion c.f. is correct, the U.S.A. was cutting each year 20 billion c.f. more than her net increment and, at this rate, would absorb her entire remaining stock in less than forty years.[1] When the more accessible forests have been depleted the price of timber must rise and this will greatly curtail consumption, but the fact that the U.S.A. consumes nearly half the sawn timber produced in the world makes America the most important factor in the world timber market.

TABLE VII.[2] *U.S.A. Estimated population, timber production, exports and imports, consumption, and paper consumption.*

		Lumber.			*Consumption.*		*Paper Consumption.*	
Year.	*Population millions.*	*Production. m.c.f.*	*Exports. m.c.f.*	*Impts. m.c.f.*	*Total m.c.f.*	*per capita c.f.*	*Total 1000 short tons.*	*per capita lbs.*
1879	49·6	1,507	24	46	1,529	31	457	18
1889	62·3	2,254	48	63	2,269	36	1,121	36
1899	75·4	2,921	83	44	2,880	38	2,158	57
1909	90·7	3,710	191	84	3,603	40	4,224	93
1919	105·0	2,880	140	99	2,839	27	6,493	124
1923	110·7	3,097	206	166	3,057	28	9,338	169

Allowing the usual American conversion that 100 b.f. sawn is equivalent to 21·9 c.f. of standing timber, i.e. a wastage of 62 per cent., it appears that the 1909 *per capita* consumption of sawn timber represented a volume of 105 c.f. of standing timber. Paper may have represented another 6 c.f. Other uses have been estimated at about the following amounts of standing timber *per capita*: fuel 104·5, hewn sleepers 10·5, fencing 18, and other uses 21. These estimates give a grand total of 265 c.f. of standing timber utilized per head of population in 1909. This is nearly as high as the *per capita* consumption of Finland, but Table VII suggests that, not only the *per capita* consumption, but even the total consumption of timber in U.S.A. is falling.

[1] R. V. Reynolds, *American Forests*, May 1928, shows that past prophesies of timber shortage have all been too pessimistic and too little account has been taken of second growth.

[2] Converted from 'Forestry and Forest Products', U.S. Dept. of Agr. Separate from Yearbook, 1924, No. 910, compiled by W. F. Callander and others. This article contains valuable statistical information.

Imports and exports of sawn timber are shown in Table VII; in addition to these imports, pulpwood imports amounted in 1923 to 114 million c.f. and the pulp and paper imports to the equivalent of 303 million c.f. Nearly all this, as well as most of the imported sawn timber comes from Canada. On the other hand, America exports large quantities of barrel staves and timber in a manufactured form, especially as packing crates and boxes.

The remaining supplies of coniferous timber in U.S.A. are now mainly in the west. Large quantities of timber are shipped from the Pacific coast through the Panama Canal to the east coast ports, but the cost of this shipment is nearly as high as the freightage from the Baltic or White Sea. The easily obtainable supplies on the Pacific coast are adequate for a good many years, but felling in this area is much more rapid than growth, and it appears very probable that in time America will become one of the chief markets for European timber.

II

TIMBER SUPPLY AND CONSUMPTION (*contd.*)

Russia: other countries. Timber consumption: relation of *per capita* consumption to relative area of forest: consumption of timber very elastic. Outlook for the future. Consumption of wood for pulp, paper, and artificial silk: conversion factors from weight of pulp to volume of standing timber: consumption of paper and manufacture of pulp in principal countries.

Russia. European Russia is so large and covers so many types of country that very false conclusions may be drawn from regarding it as a whole. The north of Russia is densely forested and has a meagre population; it is one of the great potential areas of timber supply of the world. The south and much of central Russia is poor in forests and, since coal is not abundant, a definite shortage of timber is apparent in many parts.

The present area of forests is about 380 million acres. Over 40 per cent. of this area, or about 165 million acres, is in the northern governments of Archangel and Vologda, and this represents an area of 86 acres for each inhabitant (cf. 15 acres per inhabitant for the whole of Finland). The whole of this area drains into the White Sea or into the Petchora River which flows into the Arctic Ocean to the east of the White Sea. The north Baltic governments of Olonetz and Novgorod have a further area of 34 million acres of forest from which extraction is possible either by the White Sea or the Baltic. These governments have a denser population, but have nevertheless an area of about 23 acres of forest per head of population.

North Russia has thus an area of some 200 million acres of forest, nearly all coniferous (*Picea excelsa* and *Pinus silvestris* dominant). As this area has never been systematically cut its net timber increment is probably small, but a rough estimate of the probable volume of timber that might be exported without exhausting the forests may be obtained by comparison with the neighbouring country of Finland. Finnish forests, with an area of 62 million acres, have an estimated gross increment of about 1·5 billion c.f.; it is reasonable to suppose that northern Russia has three times this gross increment, or 4·5 billion c.f. Finland, with a population of 3·5 millions, has a home consumption of about 0·9 billion c.f.; it is reasonable to suppose that the four northern governments of Russia, with a population of rather under 4 millions, has a home consumption of about 1 billion c.f. This leaves about 3·5 billion c.f. as a possible surplus for export if the forests were conservatively managed; and very little of this is situated in areas which can supply central or south Russia.

The possible annual production from Russian forests as a whole was estimated by the Russian forest service before the war at over 30 c.f. per acre, which is probably too high. Nevertheless, the present world price of coniferous timber is too low to allow of extensive utilization in the northern forests, and it is recorded that in 1911 only 52 per cent. of the timber actually felled for sale in the governments of Archangel, Vologda, Olonetz, Wjätka, and Perm found purchasers. One of the factors which restrict utilization is the sparseness of the population and the consequent high wages and expense of housing and feeding workers. Other factors are the low density of the forests and the considerable capital sums which will be required to make rivers suitable for floating.

In southern and central Russia the demand for timber is such that nearly all trees which are put up for sale find purchasers. In addition to meeting the home demand, which is large, a considerable volume of timber is exported to Germany from the western governments by water and rail.

The total amount of timber exported from Russia rose from 4·16 million tons (*c.* 190 million c.f.) in 1903 to 7·55 million tons (*c.* 340 million c.f.) in 1913: a rise of over 80 per cent. in 10 years. These figures relate to the whole of pre-war Russia with the exception of Finland, and thus include the succession states on the eastern borders of Germany. Table VIII shows the pre-war and post-war exports from the present boundaries of the U.S.S.R.[1]

TABLE VIII. *Volume of timber, sawn and round, exported from within the present boundaries of the U.S.S.R. in* 1913 *and* 1921 *to* 1927.

Year.	*Quantity exported.* Thousand cub. metres[3]	*Quantity exported.* Million c.f.	*Per cent.* (1921/22 = 100.)
1913	7,730	273	1,050
1921/22	736	26	100
1922/23	1,754	62	233
1923/24	3,585	127	475
1924/25	3,927	139	521
1925/26	3,312	117	439
1926/27	4,117	145	547

The proportion of the timber sawn before export was about 50 per cent. both in 1913 and in 1926/27, but it was rather less in intervening years. Britain, however, which absorbs about half of Russia's exports (47·4 per cent. in 1926/27), took more than 78 per

[1] *Timber Trades Journal*, 13 June 1928, p. 57: 'from an official source'.

cent. of the sawn exports in the same year. The White Sea ports handle almost exactly half of Russia's timber exports and a quarter passes through the Baltic. About 14 per cent. passes through the far eastern border, mostly to Japan, and the only remaining export channel of importance is the western border, through which 8 to 9 per cent. passes, mostly to Germany.

From Table VIII it will be seen that there has been a considerable recovery in Russian timber exports since the war, but that they only amount to half the volume exported in 1913. The export from northern Russia in 1926/27 was about 77 million c.f., which may represent 150 million c.f. of standing timber; this is less than 5 per cent. of the volume which was estimated above (p. 27) as the possible surplus for export from the northern governments of European Russia.

Other Countries. The new countries which were carved out of Russia and Austria-Hungary by the Versailles Treaty have all increased their export of timber since the war. These countries are Estonia, Latvia, Lithuania, Poland, Czechoslovakia, Jugoslavia and, in some measure, Austria and Rumania. They have all had difficulty in stabilizing their currencies, and in order to preserve their trade balance they have encouraged the export of timber in every possible way. It is probable that during the post-war years each of these countries has been overfelling to such an extent that their output cannot be maintained for many years. Austria was cutting more than twice her increment before the war, and since exploitation has been accelerated, the standing volume in the country must be greatly reduced each year.

Those countries which can export through the Baltic compete in the markets which were previously served by Scandinavia and Russia, and their entry has had the effect of keeping down the London price of timber. In 1927 Britain took nearly 80 per cent. of the sawn coniferous exports of Poland, but this was due largely to a tariff war between Poland and Germany.[1] Since the settlement of this controversy in 1928 Germany has allowed an import of $1\frac{1}{4}$ million cubic metres of sawn timber from Poland. The tariff policy of Germany has been directed towards encouraging the import of timber in the round so that the profits of conversion might be earned in Germany and, since over 70 per cent. of her timber imports come from Poland and Czechoslovakia, most of which can be floated across the frontier, this policy is not so wasteful as it would be if followed by

[1] J. L. Elkman, loc. cit. See also *Economic Conditions in Poland* (1928) by R. E. Kimens, issued by the Department of Overseas Trade.

Britain. The settlement of the tariff war greatly increased the export of timber, both round and sawn, from Poland to Germany, and the export to Britain has been reduced to a small amount.

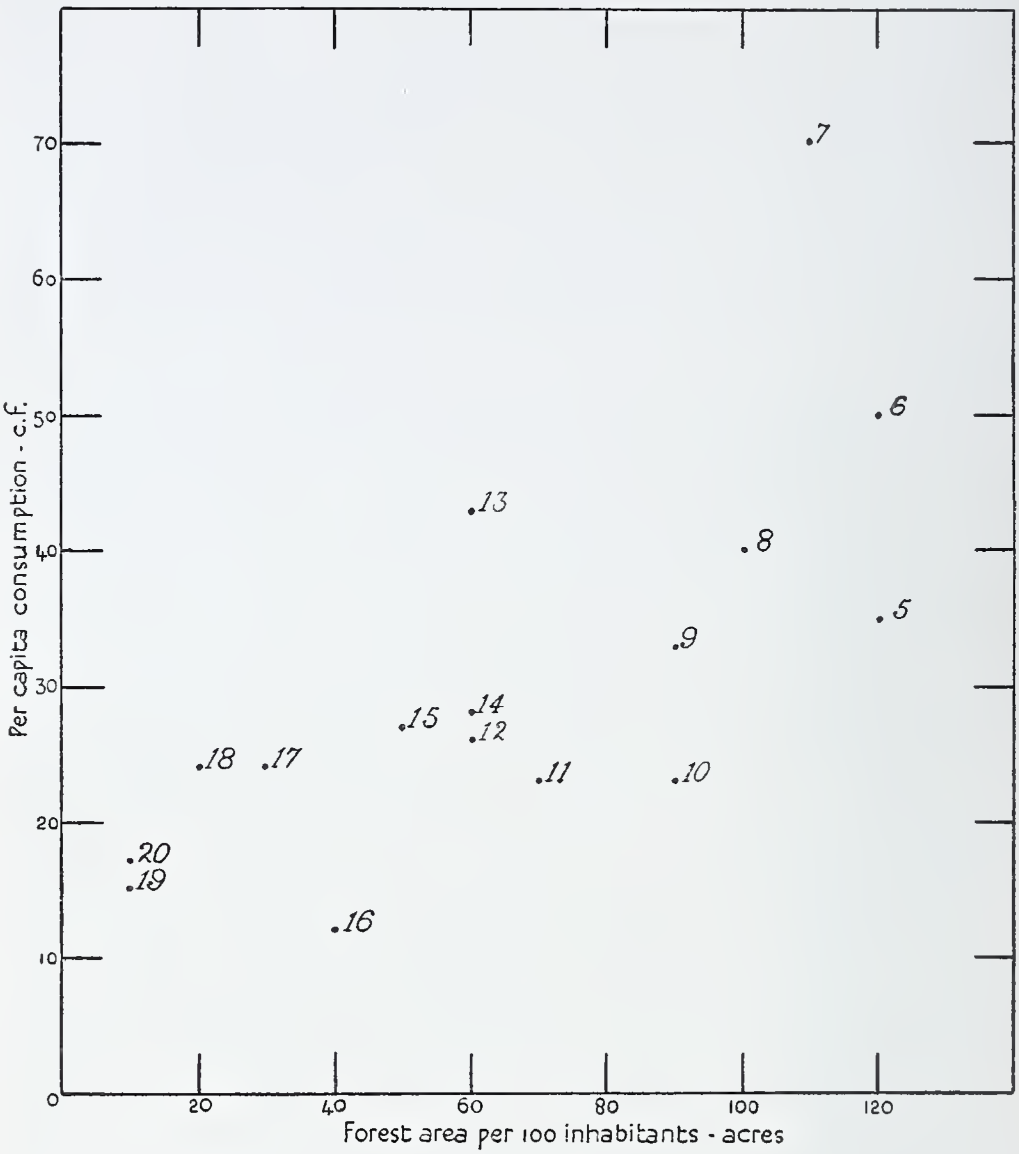

FIG. 1. Diagram showing the relationship between forest area per 100 inhabitants and *per capita* consumption in various European countries. For key to numbers see Table IX.

Timber consumption. Figures for the timber consumption of most countries are very unreliable. Not only is it difficult to assess the volume used by the forest inhabitants for firewood, which comprises about half the timber consumption of the world, but countries which import their supplies generally reckon consumption in terms of

TABLE IX. *Northern and Central Europe. Forest area per* 100 *inhabitants and* per capita *consumption.*

No.	Country.	Forest area per 100 inhabitants. acres.		Per capita consumption. c.f.	
1	Finland	1,470	mean 880	299	mean 153
2	Sweden	960		129	
3	Norway	650		118	
4	Russia	440		66	
5	Austria	120	mean 105	35	mean 42
6	Latvia	120		50	
7	Estonia	110		70	
8	Lithuania	100		40	
9	Czechoslovakia	90		33	
10	Poland	90		23	
11	Luxembourg	70	mean 60	23	mean 29
12	France	60		26	
13	Alsace Lorraine	60		43	
14	Switzerland	60		28	
15	Germany	50		27	
16	Hungary	40	mean 22	12	mean 18
17	Denmark	30		24	
18	Belgium	20		24	
19	Great Britain and Ireland	10		15	
20	Netherlands	10		16	

sawn wood, whereas well forested countries compute consumption in terms of standing timber. Although, for these reasons, no great trust must be put in published statistics the differences in the rate of consumption in various countries are so great that it is possible to deduce some general conclusions as to the reasons which determine the *per capita* consumption.

Table IX shows the countries of northern and central Europe arranged in the order of the area of forest per 100 inhabitants, and the estimated *per capita* consumption in those countries (figures extracted from Zon and Sparhawk). This table shows that very large *per capita* consumption only occurs in countries with very large relative areas of forest, and that consumption is roughly proportional to forest area per inhabitant. The same principle holds good even with less densely forested countries, as is shown by Fig. 1, which is a graph associating the two variables.

The high consumption in well-forested countries is due partly to the extravagant use of wood by forest dwellers who generally obtain timber free and use it for housebuilding, fuel, fencing, and all other possible purposes, and partly to the cheapness of timber in areas not

far distant. In Britain timber is comparatively dear, and not only is coal a cheaper fuel for general purposes but all sorts of substitutes find a ready use. Thus the most important factor which influences the *per capita* consumption of wood is the relative cheapness of wood and other commodities which may be used as substitutes.

It is probable that the next most important factor is the rate at which the population of a country is growing. Large timber is principally used for house-construction, and a country which has a rapidly increasing population has much more need of new houses than one whose numbers are constant or falling. Evidence for this will be found in the chapter dealing with British imports, and it is probable that the large timber consumption in the U.S.A. is partly to be attributed to this cause.

A third factor is the degree of industrialization in a country. A highly industrialized country is characterized by commodious houses and numerous factories and other buildings which must affect the volume of wood used per unit of population. Paper consumption is also much larger among industrial than rural populations. But these tendencies are to some extent counterbalanced by the substitution of metal and concrete for timber, not only in building but in office furniture and other uses. If the points representing such countries as Britain, France, Germany, Holland, and Belgium are picked out in Figure 1 it is not apparent that the timber consumption per head of population in these countries is markedly higher than in other countries with the same relative area.

The results obtained by Chapman and Miller,[1] who conducted an inquiry into the timber consumption in the state of Illinois, are interesting in this connexion. Originally, more than 40 per cent. of Illinois was covered by forest and, consequently, the population may be expected to have acquired the tradition of extravagant timber consumption which is characteristic of America. By 1924, however, the forests were reduced to 8 per cent. of her area, and these forests were largely depleted, so that all but 2·4 per cent. of the sawn timber used in the state was imported. It was estimated in 1924 that the annual *per capita* consumption of all wood and timber, expressed in terms of standing timber but exclusive of wood pulp, was about 86 c.f. As the average *per capita* consumption in U.S.A. as a whole was over 200 c.f. it appears that the *per capita* consumption in Illinois was considerably less than half the average, which exemplifies the generalization that, as a country loses its home supplies of

[1] H. H. Chapman and R. B. Miller, *Second Report on a Forest Survey of Illinois. The Economics of Forestry in the State.* State of Illinois, Urbana, Illinois, 1924.

timber and becomes dependent on imports, its *per capita* consumption becomes greatly reduced.

This observation and the evidence already given from Europe go to show that the price of wood, and its relation to the prices of other commodities, is the controlling factor in determining the amount of timber consumed. Where wood is cheap it is used for very many purposes for which substitutes are found where wood is dear. In the language of economists the consumption of wood is very elastic, a fact which has generally been overlooked in discussions on the future of timber supplies.

Outlook for the future. It is generally conceded that in studying the problem of the future timber supply, especially the question whether the world's forests will continue to supply sufficient timber to meet the requirements of the world's population, it is necessary to distinguish between the market for conifers or softwoods and broad-leaved trees or hardwoods. The uses of the two types of timber are now well defined, and the one type is not generally replaceable by the other. Coniferous timber is obtainable in large bulk, is easily extracted where waterways exist, is cheap to saw and easy to work. It is therefore used for all ordinary structural purposes and is in far greater demand than broad-leaved timber. Indeed, more than 90 per cent. of the timber imported into Britain is coniferous. Hardwoods are used for special purposes where extra strength, durability, or good appearance are required, and where the additional price can be met. In localities where hardwoods occur they are largely used for firewood as well as general purposes but, even in countries which have only hardwoods, the greater ease in working softwoods generally creates a demand for imported coniferous timber.

Owing to the existence of very large areas of tropical forest which are capable of producing immense quantities of hardwoods, no fears are entertained as to world shortage of broad-leaved timbers as a whole. Certain species may run short, and there is little doubt that oak is being cut much faster than it is being produced. But if oak becomes unduly expensive it will be fairly easily replaced by tropical hardwoods with similar properties. Ash may be more difficult to replace. U.S.A. is using up its hardwoods even more rapidly than its conifers, but owing to the possibility of deriving hardwood supplies from South America, this causes less general concern than the prospect caused by the devastation of the coniferous forests.

The anxiety about future timber supplies is thus centred round

the softwood market. The coniferous forests of the world are almost confined to the north temperate zone, most of which is becoming industrialized. These forests are being cut much faster than they are growing, and in some of them, notably in America, exhaustion is in sight.

The statistical evidence for an approaching timber famine has been advanced by Fraser Story[1] in England and Zon and Sparhawk[1] in America. The former gives the area of coniferous forest, volume of standing timber, annual cut and increment, imports and exports, for all European countries, and reaches the conclusion that Europe consumes 9·43 billion c.f. of coniferous timber (standing volume), which is 3·36 billion c.f. more than her net increment.[2] Russia alone is credited with cutting 1·6 billion c.f. more than she grows. The alarmist prognostications founded on Fraser Story's statistics have failed to convince the timber trade which, in general, takes the view that sufficient timber remains in the forests for all visible needs, and a re-examination of the position suggests that the trade has much justification for its attitude.

The large deficit which Fraser Story has calculated is the difference between the annual cut and the annual net increment. Such a deficit implies that a part or the whole of the forests which are at present being worked is gradually being depleted, and there is no doubt that in certain countries, particularly in the succession states that have been formed between Russia and Germany, overcutting is going on to a serious extent. This is a real cause for alarm to those countries which are overcutting, but it must not be assumed from Fraser Story's calculations that Europe, as a whole, is running short of timber since they take no account of those areas of forest which are not being worked.

Virgin forest has no net increment and consequently has no influence on the timber deficit as computed by Fraser Story. Such forest, however, may in the course of time provide large amounts of timber, and only when it is utilized does it start to have a net increment. Thus, so long as areas of unworked forest still exist the net increment is not a true measure of continuous productive capacity.

Such an area of unworked, or little worked, forest exists in northern Russia and this area must carry a timber stock of between 100 and 200 billion c.f. of coniferous timber[3] and, if reasonably well managed, it should provide some 3·5 billion c.f.[4] for annual

[1] Loc. cit.

[2] A re-examination of Fraser Story's figures suggests that the excess is 2·3 billion c.f.

[3] By comparison with the known volume in Finland. See pp. 19 and 28. [4] See p. 28.

export without overcutting. Allowing 50 per cent. for wastage in conversion, this is equivalent to an export of 1·7 billion c.f. of sawn timber, which exceeds the total volume of sawn coniferous timber at present annually exported from all European countries.

At present prices much of this material is unmerchantable, but, if a timber shortage occurs, prices will automatically rise and more and more of this timber will become available. The present price of timber is unduly low owing to over-cutting in the succession states, but, when these supplies become curtailed, prices may be expected to rise and Russian timber should enter in larger and larger quantities into the world market.

Price changes [1] act as a useful buffer between the needs of mankind and famine, and, with a commodity such as timber, of which fresh supplies become available if the price is raised, this buffer should be effective in preventing any sudden shortage. Since the population of the civilized world is still increasing, the consumption of timber, if prices remained constant, might be expected to increase. When, however, prices rise, as they must do immediately a shortage is felt, then the effective demand will be reduced.

This curtailment in demand through rise in price should be most effective in reducing consumption in timber-producing countries. For an increase of £1 per standard in the c.i.f. London price of Finnish timber, which is equivalent to a rise of about 6 per cent., may be expected to bring about an increase of 1*d.* per cubic foot in the value of timber standing in Finland, which is equivalent to a rise of 40 per cent. on the present standing value.[2] If prices doubled in London, standing timber which is now worth 2½*d.* per cubic foot might come to be worth 1*s.* 6*d.*, and the owner of such a valuable commodity would be much more careful to prevent wasting it than he is at present. For this reason a rise in price should increase the surplus volume of timber which Finland can export.

It thus appears that if left to herself Europe could continue to meet her needs in the matter of coniferous timber for a long period to come, though at a higher price than at present. The real danger of a shortage arises from the enormous consumption in U.S.A. The annual consumption of all kinds of timber in U.S.A. is about 24 billion c.f. and her net increment is assessed at 4 billion c.f. U.S.A. is already beginning to import timber from Europe and, though her markets are at present flooded with timber from her own Pacific Coast, European shippers can, and do, sell timber at

[1] See chapters iv and v.

[2] See Hiley, *Forest Industry of Finland*, Oxford For. Mem. No. 8, 1928.

a profit in some of the markets of the Eastern States. The present rate of extraction in the Western States can scarcely continue for another generation, and it appears likely that European timber will then be shipped to America in large quantities. If this occurs the rise in timber prices might become rapid.

As shown in Table II (p. 18), about 60 per cent. of the coniferous forest of Europe falls within the frontiers of Russia. The whole of this area is nominally controlled by the Russian state, and consequently the forest policy of the Russian government must have a preponderating influence on the future of Europe's coniferous supplies. As long as prices are such that only a small part of this forest contains merchantable timber there will be no far-reaching incentive towards devastation except in so far as it is demanded by the peasants. But when timber prices rise great havoc may be wrought in these forests unless the forest administration exerts a powerful hold over their management so that they may be cut on a principle of sustained yield.

Consumption of wood for pulp, paper, and artificial silk. The manufacture of wood-pulp, paper, and artificial silk constitutes a very important part of the industries based on forest products. The importance of these industries is due less to the volume of timber which they consume than to the large amount of capital which is required for the erection of mills and the marketing of the products. The wood which is used for pulp in Europe is principally the thinnings from coniferous forests, and the favourable financial returns from spruce and silver fir forests is largely due to the fact that these species are particularly suitable for pulp manufacture. It is unusual for more than a small proportion of the total cut in these woods to be used for pulp since timber which is large enough for sawing is more profitably employed in this way, but the financial returns from forests are greatly enhanced by the existence of a good market for thinnings which are too small for the sawbench.

In eastern Canada and eastern U.S.A. most of the accessible timber of saw size has already been extracted and, since trees grow slowly in this climate, it is often found more profitable to work forests purely for pulpwood purposes, and the large capital sunk in mills which draw timber from neighbouring forests acts as a powerful incentive towards the conservative management of those forests. If the forests are used up the value of the mills will be seriously reduced; so the companies are concerned to secure a continuous supply of timber from a limited area. The capital invested in pulp and paper companies in Canada alone amounts to over £100,000,000,

or three times the capital invested in the Canadian lumber industry.

It is by no means easy to obtain accurate statistics of the amount of timber annually consumed in making pulp and paper. Figures of total paper production are unreliable, and owing to the differences in the timbers used and in the methods of manufacture varying amounts of timber are consumed in producing a ton of pulp. Paper is composed of pulp and other ingredients, though newsprint, which constitutes the greater part of the paper which is manufactured, is nearly pure pulp.

CONVERSION FIGURES FOR PULP. Amounts of pulp wood are generally calculated in stacked measure. The English stacked measure is a cord (128 c.f.) which is equivalent to about 90 c.f. of solid wood; if stacked with bark on 12 to 18 per cent. must be deducted for bark. The metric measure of stacked wood is the 'Raummeter' or 'Stère' (1 cubic metre), which is equivalent to about 0·7 cubic metre of solid wood with the same deduction for bark if necessary. The following estimates refer to solid measure without bark.

Various equivalents have been used for the conversion of pulp into standing volume. Reinhold[1] used conversion factors which, when converted into English measure, are equivalent to 92 c.f. of spruce or 110 c.f. of pine for 1 metric ton (2,200 lb.) of mechanical pulp: 166 c.f. of spruce or silver fir for 1 metric ton of sulphite pulp and 131 c.f. for 1 metric ton of sulphate pulp. Zon and Sparhawk, on the other hand, estimated that 110 c.f. of wood went to each short ton (2,000 lb.) of dry mechanical pulp and 240 c.f to each ton of chemical pulp. Statistics for the various provinces of Canada[2] suggest that mechanical pulp takes from 79 to 107 c.f. per ton; sulphite pulp 148 to 190 c.f.; and sulphate pulp 130 to 165 c.f. Fraser Story[3] takes 1 ton of pulp as equivalent to 125 c.f. Since comparatively little pine is used for pulp, and since much more sulphite pulp than sulphate pulp is manufactured it appears that approximately accurate results may be obtained by assuming that a metric ton of mechanical pulp absorbs 95 c.f. and a metric ton of chemical pulp absorbs 160 c.f. of wood.

AMOUNT OF WOOD USED. According to Krawany[4] the amount of paper annually produced in the world is 17·7 million metric tons,

[1] *Die Papierholzversorgung*, Berlin, 1927.

[2] Canada Dep. of Trade and Commerce, Dom. Bur. of Statistics. For. Prod. Branch. Report on Pulp and Paper Industry in Canada for 1926.

[3] Loc. cit.

[4] *Internationale Papierstatistik*, Vienna, 1925.

of which about 12 million tons is made from wood, the remainder being manufactured from old paper, rags, straw, esparto, bamboo, &c. If this 12 million tons is made half from mechanical pulp and half from chemical pulp, and if the weight of the waste in converting to paper is equal to the weight of substances added, then the total volume of wood used is $570+960=1,530$ million c.f. Zon and Sparhawk estimated that the total amount of wood pulp which would have been produced in the world in 1919 if all mills were working at full capacity was 13·3 million short tons which, with their conversion factors, corresponds to a consumption of 2,300 million c.f. They suggest, however, that the actual production was probably not more than three-quarters of this, which would correspond to a consumption of 1,700 million c.f. This is probably too high an estimate for 1919, but it is fairly safe to estimate the average consumption at between 1·5 and 2·0 billion c.f.

In 1927 Reinhold estimated the annual consumption of paper per head of population in the more important consuming countries to be as shown in Table X. The equivalent volume of standing

TABLE X. Per capita *consumption of paper, and corresponding timber volumes, in principal countries.*

Country.	*Weight of paper consumed* per capita *lb.*	*Equivalent volume of standing timber. c.f.*
U.S.A.	147	8·5
Great Britain	72	4·2
Sweden	53	3·1
Norway	53	3·1
Finland	51	3·0
Holland	50	2·9
Germany	48	2·8
Switzerland	33	1·9
France	31	1·8
Austria	26	1·5
Italy	18	1·0
Spain	14	0·8

timber has been added. Other estimates, however, differ very widely from this table, and it is unsafe to attach much weight to it. The total amount of paper consumed is rising rapidly, and the consumption in the U.S.A. alone rose from 1,482,000 tons in 1914 to 2,778,000 tons in 1923, so that in nine years it nearly doubled.[1]

[1] For figures of *per capita* consumption of paper in U.S.A. from 1879 onwards see p. 25.

It appears, however, that there must be some limit to the possible consumption of paper even in America.

Table X *a* shows the amount of pulp manufactured in the principal producing countries in 1925 as estimated by Reinhold. The

TABLE X *a*. *Manufacture of pulp in principal producing countries in 1925 (Reinhold).*[1]

Country.	*Mech. pulp.* 1,000 *metric tons.*	*Chem. pulp.* 1,000 *metric tons.*	*Corresponding volume of standing timber. million c.f.*
U.S.A.	1,462	2,132	480
Canada	1,471	1,075	312
Sweden	439	1,294	249
Germany	737	913	216
Finland	295	367	87
Norway	281	370	86
Japan	?	422	68+
France	350 (in 1913)	100 (in 1924)	49
Austria	89	176	36
Great Britain	? (very little)	170 (in 1922)	27+
	5,124+	7,019	1,610+

figures for chemical pulp in this table probably include a considerable amount which is not made from wood, and since other countries produce a very small quantity of pulp of any sort it is probable that the total estimate of the amount of wood consumed is too high. The estimate on p. 38 that the average annual consumption of wood for pulp is between 1·5 and 2·0 billion c.f. is as accurate as can be expected.

ARTIFICIAL SILK. Artificial silk is made partly from wood and partly from cotton. Viscose silk is manufactured from wood, and in 1924 about 55,000 metric tons (88 per cent. of all the artificial silk manufactured) was made from wood, and as this represents only 0·5 per cent. of all the pulp manufactured, it is clear that the demand for artificial silk is not likely seriously to deplete the world's forests.

FUTURE SUPPLIES OF PULP. Although the future supply of pulpwood is not sufficiently assured to allay all apprehension, it is a matter of less anxiety than the future provision of timber. Zon and Sparhawk estimated that the possible maximum sustained production of wood pulp is about 13 million short tons, which is very little more than the present production. As advance in civilization is always accom-

[1] According to Craig (1928) the production of newsprint in North America amounted in 1927 to 3,789,433 (short?) tons. Canada produced 2,086,949 tons, U.S.A. 1,485,495 tons, Newfoundland 202,852 tons, and Mexico 14,137 tons.

panied by an increasing *per capita* consumption of paper the demand for wood pulp must necessarily increase, and at first sight it appears unlikely that this enhanced demand can be met. But Zon and Sparhawk's estimate is based on the available area of coniferous forest, whereas, with technical improvements in the manufacture of paper, more use is being made of the timber of broad-leaved trees. In addition to poplar, which is frequently used in mixture with conifers, paper is now being manufactured from species of eucalyptus which can be grown on a very short rotation. Plantations have been started in Portugal with the object of growing eucalyptus for pulp on a rotation of less than ten years. Bamboos also yield a considerable amount of fibre suitable for pulp. Further, any considerable rise in the price of pulpwood would make it worth while to cultivate conifers on very short rotations for this purpose, and many thousands of acres of fast growing species have already been planted in New Zealand and elsewhere with the object of producing wood of this nature. There is not likely to be any serious shortage of a commodity which can be produced on a short rotation, and the growing use of wood for paper may be expected, by providing a market for thinnings, to have a very favourable effect on the finance of forest cultivation.

III

BRITISH TIMBER IMPORTS AND CONSUMPTION [1]

Imports in 1927: source of principal products and their c.i.f. values. Analysis of imports from 1843 to 1928: effect of shortage of timber on British house-building: gradual slowing off in increase in imports. Consumption in terms of standing timber: conversion from sawn to standing volume: home-produced timber. *Per capita* consumption.

Imports in 1927. The volume of timber annually imported into the United Kingdom is recorded in the Board of Trade Returns. The imports are classified into many categories and, unfortunately, these categories are not all presented in terms of the same unit. Hardwoods, both hewn (i.e. round or roughly squared) and sawn are quoted in terms of cubic feet and all other categories in terms of loads. This makes both the summation of the total and the comparison of amounts and prices of different categories unnecessarily difficult and, in the interests of clarity, all volumes have in this chapter been converted to cubic feet. The timber imports for 1927 are shown in this unit in Table XI. A load of sawn timber is 50 c.f., but a load of round timber is an amount which occupies 50 c.f. of storage space and is consequently a quantity which is not exactly determinable in terms of cubic feet. It is considered that the nearest equivalent of a load of round timber is 40 c.f., and this multiplier has been used for converting the amounts of all hewn softwood and pit props. In earlier records the imports of certain hardwoods were expressed in tons and not in cubic measure. This unit has been converted to cubic feet for the purpose of Table XIII, p. 46, and a conversion factor of 40 c.f. to 1 ton has been used.

The total volume of timber imported in 1927 was 517 million c.f., which is greater than in any other year except 1913, when imports totalled 532 million c.f. Of this amount only 36 million c.f., or 7 per cent., is definitely recorded as being hardwood, and of the categories in which the nature of the wood is not specified all but a very small amount is coniferous. It is thus safe to say that less than 10 per cent. of the British timber imports is hardwood and more than 90 per cent. is coniferous. Of the hardwoods 17 million c.f., or about half, comes from U.S.A., the principal species being walnut, oak, and poplar.

[1] Stobart, *Timber Trade of the United Kingdom*, London, 1927, gives an interesting analysis of the Board of Trade Returns for British Timber Imports.

Table XI.

British timber imports for 1927. Board of Trade Returns.

	Volume c.f.	Value £	Price per c.f. Shillings.
Hewn, Hard—			
Mahogany (all sources)	2,287,097	596,260	5·2
All other sorts:			
Russia	16,378	2,996	3·7
Finland	131,750	10,501	1·6
United States of America	700,421	141,696	4·1
British East Indies	79,034	43,919	11·1
Canada	321,305	77,935	4·8
Other Countries	2,714,782	428,767	3·2
Total	3,963,670	705,814	3·6
Total, Hewn, Hard	6,250,767	1,302,074	4·2
Hewn, Soft—			
Russia	2,154,680	127,938	1·2
Finland	2,925,320	148,892	1·0
Sweden	1,101,920	104,136	1·9
Norway	1,251,040	122,957	2·0
Germany	82,480	4,673	1·1
United States of America	2,218,520	434,583	3·9
Canada	657,040	111,144	3·4
Other Countries	2,406,960	188,842	1·6
Total, Hewn, Soft	12,797,960	1,243,165	1·9
Total, Hewn	19,048,727	2,545,239	2·7
Sawn, Hard—			
Mahogany (all sources)	1,680,813	609,376	7·2
All other sorts:			
Finland	839,831	105,860	2·5
Poland (including Danzig)	1,261,085	224,811	3·6
Japan	462,738	157,995	6·8
United States of America	16,432,653	3,868,581	4·7
British East Indies	1,663,250	853,767	11·3
Canada	3,824,812	605,921	3·2
Other Countries	3,665,481	1,028,627	5·6
Total	28,149,850	6,845,562	4·9
Total, Sawn, Hard	29,830,663	7,454,938	5·0

	Volume c.f.	*Value* £	*Price per c.f.* *Shillings.*
SAWN, SOFT—			
Russia	57,180,750	5,651,006	2·0
Finland	85,738,050	7,361,038	1·7
Latvia	21,933,800	1,897,808	1·7
Sweden	46,121,750	4,219,700	1·8
Norway	6,879,250	672,334	2·0
Poland (including Danzig)	40,210,150	3,413,510	1·7
Germany	2,791,650	248,252	1·8
United States of America	11,780,650	1,869,657	3·2
Canada	15,788,050	1,774,796	2·2
Other Countries	12,868,150	1,138,904	1·8
Total, Sawn, Soft	301,292,250	28,247,005	1·9
Total, Sawn	330,122,913	35,701,943	2·2
PLANED OR DRESSED—			
Finland	3,710,450	399,212	2·2
Sweden	21,190,200	2,480,754	2·3
Norway	7,688,300	908,161	2·4
Germany	90,350	10,238	2·3
United States of America	256,550	57,522	4·5
Other Countries	1,494,950	182,980	2·5
Total	34,430,800	4,038,867	2·3
OTHER DESCRIPTIONS—			
Pitprops or Pitwood:			
Finland	26,909,640	1,515,830	1·1
Sweden	13,316,600	827,179	1·2
Norway	3,459,840	230,557	1·3
France	45,523,640	1,494,798	0·7
Portugal	2,857,520	93,396	0·7
Other Countries	22,492,480	1,296,064	1·2
Total	114,559,720	5,457,824	1·0
Staves of all dimensions	5,207,950	739,871	2·8
Sleepers of all kinds	12,419,500	963,177	1·6
Veneers and Panel Wood	190,150	205,703	21·6
Not elsewhere specified	143·450	17,995	2·5
Total of Wood and Timber	517,123,210	49,670,619	1·92

Sawn softwood constitutes about 58 per cent. of our imports, and the more important supplying countries are Finland, Russia, and Sweden. Poland sent us large supplies in 1927, but the imports from this country cannot be expected to be so high again. The

highest price is paid for imports from America, which include pitch pine and Oregon pine (Douglas fir) as well as a little high class white pine. The lowest prices are paid for timber from Finland, Latvia, and Poland; this is partly due to the fact that these countries are newer in the market than Norway or Sweden, and have to offer goods at a low price in order to get sales, and partly to the smaller size and lower quality of much of the material shipped. Nearly all these imports from northern Europe are red deal (*Pinus silvestris*) or white deal (*Picea excelsa*). Planed and dressed wood is sent us principally by Sweden. This is a sign of the highly developed nature of the Swedish timber industry which is assisted by the good quality of the timber grown in this mountainous country.

Pitprops amount to 120 million c.f. or 22 per cent. of the total import. These are of small size, imported in the round and generally barked, and the low price of 1*s.* a cubic foot is due to the fact that the timber is too small for sawing. Nearly half of our imported pitprops come from Les Landes in southern France, where they form a by-product of the resin industry. These trees have been damaged by tapping, and can be bought for about 8*d.* a cubic foot, c.i.f.[1] Sweden and Finland send us chiefly Scots pine for pitprops, since their small spruce fetches a higher price as pulpwood.

Among other specifications veneers (including plywood) reach remarkably high prices. 'Not elsewhere specified' comprises chiefly split chestnut coppice used for fencing, barrel hoops,[2] &c., and comes principally from France.

TABLE XII. *Value of imports and exports of wood and wood products in* 1927.[3]

Commodity.	*Imports.*	*Exports.* *Produce and manufacture of U.K.*	*Exports.* *Imported merchandise.*
	£	£	£
Timber	49,670,619	539,738	741,271
Manufactures of wood and timber	7,313,916	2,316,957	561,299
Paper-making materials[4] . .	12,792,944	1,367,363	52,943
Paper and cardboard . . .	16,430,793	9,134,091	321,470
Total . .	86,208,272	13,358,149	1,676,983

[1] *C.i.f.* (cost, insurance, freight) price is the price at wharfside in the country of import.; f.o.b. (free on board) price is the price when loaded on ship in the country of export.

[2] T. J. Stobart, *Timber Trade of the U. K.*, London, 1927.

[3] From *Board of Trade Journal*, 19 January 1928.

[4] This category includes other paper-making materials in addition to wood pulp.

Table XII has been included in order to complete the survey of timber imports, and shows the value of timber and manufactures from timber which were imported and exported in 1927. This table shows that the value of the net imports, i.e. imports less exports and re-exports, was about £71,000,000.

Analysis of Imports from 1843 to 1928. The history of British timber imports is closely associated with the development of the social institutions of the country. England is entirely lacking in native coniferous timber trees, and even in Scotland the distribution of pine is confined to the highlands which until recently were inaccessible. Our traditional architecture is based on hardwoods, especially the oak, and, since even hardwoods have for many centuries been scarce, wooden buildings are comparatively rare. In other countries of northern Europe buildings in country districts are commonly of wood, and for this reason the medieval stone-built villages of England are a feature almost unique among northern countries. They have their counterpart in the Mediterranean states which, like England, are deficient in coniferous timber.

Britain has been a timber importing country from the twelfth century onwards, and imports both of hardwoods and conifers were considerable in the fourteenth century; but continuous statistics are lacking for years previous to 1843, when regular government records were instituted. At first only hewn wood, sawn wood, and staves were distinguished as separate categories, and these were recorded in loads. During the fifties mahogany and teak were further differentiated, but not until 1891 were conifers distinguished from hardwoods; thus the present day detailed statistics have been gradually developed.

Table XIII shows the imports, from 1843 to 1928, expressed in terms of cubic feet. This period has been characterized by great increase both in population and industrial activity, and the growth of timber imports is phenomenal. But the rate of increase, which was very rapid during the middle of the last century, has fallen off very much since, as is clearly seen in Table XIV.

Table XIII. *British timber imports.*

Year.	*Total imports (imported vol.) million c.f.*	*Proportion sawn* %	*Total imports (corresponding standing vol.) million c.f.*	*Quinquenn. average million c.f.*	*Increase in quinquenn. period* %
1843 . .	61·7	54·2	95		
1844 . .	70·3	56·9	110		
5 . .	91·5	53·0	140		
6 . .	92·7	46·0	135	130	
7 . .	87·4	52·9	134		
8 . .	83·1	55·2	129		
1849 . .	77·2	57·6	122		
1850 . .	78·5	55·8	122		
1 . .	99·2	55·6	154	150	15
2 . .	97·3	62·0	158		
3 . .	120·6	60·8	194		
1854 . .	117·7	58·4	186		
5 . .	88·5	56·6	139		
6 . .	117·1	61·2	189	177	18
7 . .	120·5	59·3	192		
8 . .	109·1	62·3	177		
1859 . .	127·1	62·4	206		
1860 . .	129·9	58·8	206		
1 . .	145·1	61·1	234	229	30
2 . .	137·2	58·8	218		
3 . .	171·2	63·2	279		
1864 . .	177·5	64·6	292		
5 . .	195·1	64·1	320		
6 . .	187·6	67·0	313	312	36
7 . .	175·4	70·8	300		
8 . .	194·7	71·2	333		
1869 . .	188·4	70·9	322		
1870 . .	208·4	71·9	358		
1 . .	214·7	68·6	362	374	20
2 . .	231·0	68·4	389		
3 . .	261·2	67·4	437		
1874 . .	298·7	66·4	497		
5 . .	240·9	70·6	411		
6 . .	306·1	71·0	524	486	30
7 . .	320·7	73·3	556		
8 . .	255·5	72·9	442		

[*Continued on p. 48.*

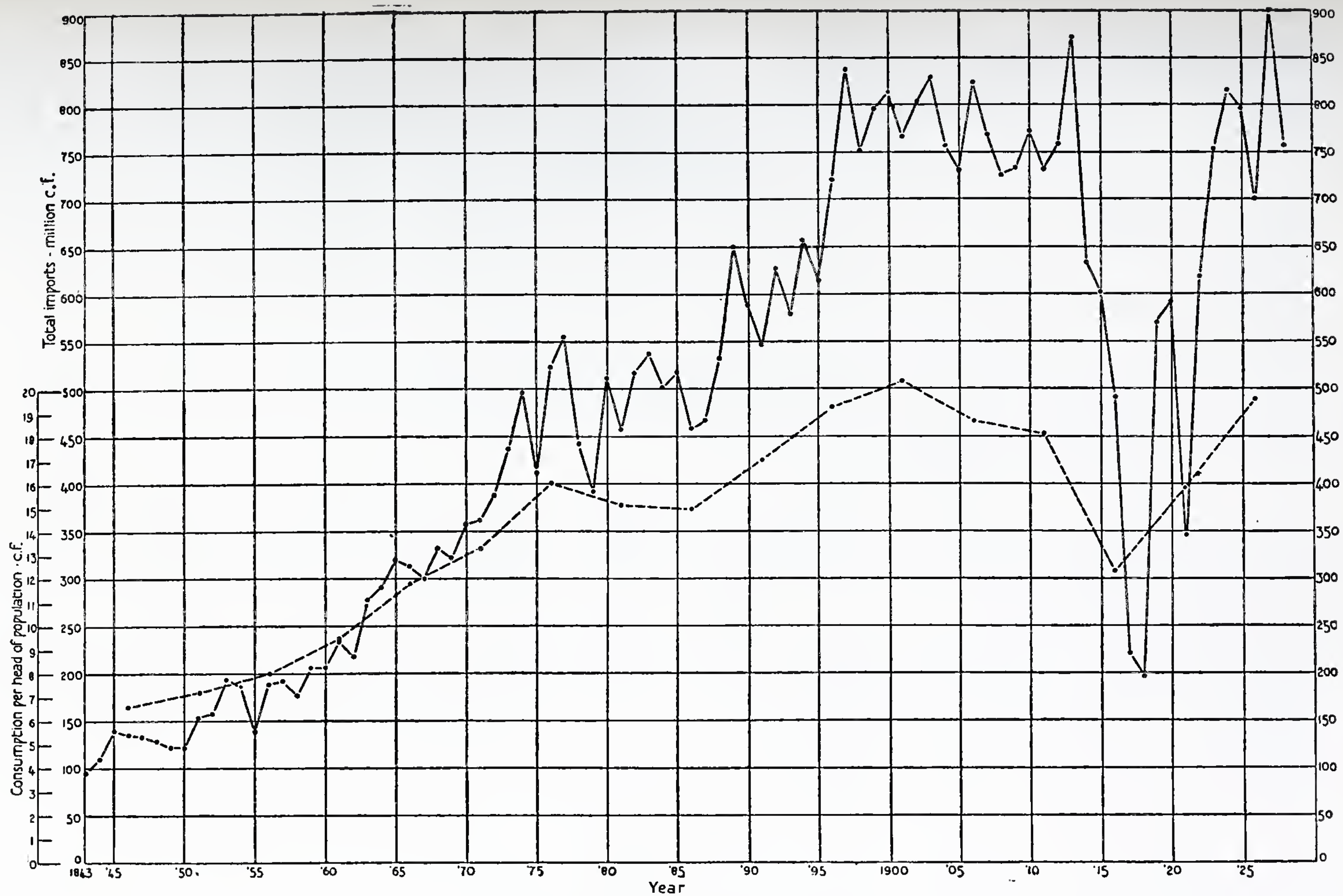

FIG. 2. Timber imports into Britain, in terms of standing timber, and *per capita* consumption for each quinquennial period, 1843–1928.

Year.	*Total imports (imported vol.) million c.f.*	*Proportion sawn.* %	*Total imports (corresponding standing vol.) million c.f.*	*Quinquenn. average million c.f.*	*Increase in quinquenn. period* %
1879 . .	225·5	74·1	393		
1880 . .	299·4	70·5	511		
1 . .	268·2	70·7	458	484	0
2 . .	300·7	72·6	519		
3 . .	313·4	71·1	537		
1884 . .	292·1	71·6	502		
5 . .	299·9	72·7	518		
6 . .	263·1	74·4	459	496	2
7 . .	269·2	73·0	466		
8 . .	308·8	72·9	534		
1889 . .	374·8	73·3	650		
1890 . .	342·7	72·0	589		
1 . .	321·0	70·2	547	599	21
2 . .	365·9	71·4	627		
3 . .	336·0	72·7	580		
1894 . .	378·5	73·7	658		
5 . .	356·0	73·1	616		
6 . .	413·4	74·6	722	717	20
7 . .	479·3	74·6	838		
8 . .	427·1	76·1	752		
1899 . .	457·4	74·0	796		
1900 . .	475·0	71·4	814		
1 . .	444·5	72·2	766	802	12
2 . .	463·8	73·3	804		
3 . .	483·7	71·1	828		
1904 . .	446·2	69·4	756		
5 . .	427·8	70·6	730		
6 . .	482·2	70·9	824	761	−5
7 . .	460·4	66·9	768		
8 . .	445·3	63·2	727		
1909 . .	440·4	66·4	733		
1910 . .	464·8	66·3	773		
1 . .	446·6	64·2	733	774	2
2 . .	461·7	64·3	759		
3 . .	531·7	64·1	872		
1914 . .	386·5	63·8	634		
5 . .	356·0	69·3	603		
6 . .	292·7	68·2	492	429	−44
7 . .	132·5	66·1	220		
8 . .	115·3	70·0	196		

Year.	*Total imports (imported vol.) million c.f.*	*Proportion sawn %*	*Total imports (corresponding standing vol.) million c.f.*	*Quinquenn. average million c.f.*	*Increase in quinquenn. period %*
1919 . .	323·8	75·9	570		
1920 . .	343·7	72·4	592		
1 . .	203·0	70·0	345	576	34
2 . .	370·9	66·8	619		
3 . .	456·7	64·6	752		
1924 . .	479·9	70·3	817		
5 . .	461·1	72·7	796		
6 . .	391·1	79·3	702	794	38
7 . .	517·1	74·2	901		
8 . .	446·2	69·4	756		

Table XIV. *Rate of increase in amount of wood imported annually into Britain.*

Years.	*Aver. vol. of wood imported Million c.f.*	*Percentage sawn before import.*	*Increase in volume of import.*
1844 to 1848 . .	85	52	234% in 30 years.
1874 to 1878 . .	284	71	59% in 30 years.
1904 to 1908 . .	452	68	1·5% in 20 years.
1924 to 1928 . .	459	74	

The increase in the percentage of wood sawn before import is due to the development of the sawing industry in exporting countries. In 1843 only 46 per cent. of the total imports (apart from staves) were sawn; more than two-thirds of this timber came from British possessions, chiefly Canada, and only 37 per cent. of these imports from the colonies were sawn. By 1866 the proportion that came from British possessions had sunk from 70 per cent. to 38 per cent., but the proportion of this timber which was sawn was 69 per cent. Since, in converting round timber to sawn, there is a waste of some 50 per cent. a great saving in freightage is achieved by sawing the timber before it is shipped, and for this reason it is impossible for sawyards in Britain to compete with those in exporting countries. The large volume of hewn wood which is still imported is chiefly used for pitwood, for which purpose very little sawing is necessary. In 1901, the first year in which pitwood was distinguished from other hewn imports in the Board of Trade Returns, pitwood formed 68 per cent. of all hewn coniferous imports, but by 1927 this proportion had risen to 93 per cent. Thus, at the present time the

proportion of hewn to sawn imports is mainly determined by the relative demands of coal mines and the building trade. The small percentage of sawn timber from 1907 till the war was due to slackness in the building trade, and the high proportion in 1926 to the stoppage of work in the coal mines in that year.

Consumption in terms of standing timber. In order to estimate the actual consumption of wood in Britain it is necessary, firstly, to correct the imports to a corresponding standing volume and, secondly, to add the home production. The first correction is necessary because the more we import in a sawn state the more waste is involved in producing it, and to import a million c.f. of round wood is clearly not the same thing as to import a million c.f. of sawn wood. The actual waste that is involved in sawing depends on the size and straightness of the trees and the intensiveness of management. Big trees give less waste than small trees, and intensive management, both in the forest and the saw mill and in the utilization of waste, may greatly economize timber. Practice in Finland, where most of the trees are small, indicates that it takes about 320 c.f. (true measure) of standing timber to make a standard (165 c.f.) of sawn timber; this is equivalent to a waste of very nearly 50 per cent. In America, on the other hand, where standing trees are measured by the 'board feet' they may be expected to yield on sawing, it is estimated that 100 b.f. is equivalent to 21·9 c.f. This indicates a waste of 62 per cent., but with economical management the actual volume of sawn timber extracted from a tree is generally greater than the volume in board feet measured according to rule. Further, the waste may not all be useless; a considerable portion, approximately one-third, is generally used as fuel to drive the sawing machinery; in north Finland the remainder is used to build up land on the foreshore for the purpose of increasing the area of timber yards; in Canada it is frequently destroyed in a consumer. In all these cases the 'waste' is definitely consumed in the production of timber. On the other hand, some mills use waste for making pulp, and certain new uses are now advertised such as the manufacture of 'Masonite', a kind of board made from crushed wood-fibre. Despite these uses of 'waste', when we bear in mind that a considerable volume of timber is frequently left in the forests or used up in the process of extraction, we cannot expect the waste to be much less than 50 per cent. and, in the absence of more precise information, we may assume that a given volume of sawn timber represents double that volume of standing timber.

The standing volume of timber corresponding to our imports may

thus be calculated as the volume of hewn imports plus twice the volume of sawn imports. Table XIII shows the magnitude of this amount for each year from 1843 to 1928. The table also shows quinquennial averages and the percentage rise or fall from one five-year period to the next. Apart from stagnation in the eighties of the last century there was a nearly continuous rise until 1903. Then for ten years the imports remained more or less stationary, though 1913 was a record year. During the war imports were greatly reduced and the pre-war rate was not again attained until 1923, and from then till 1928 the amount imported was about the same as before the war.

There are no continuous records of the volume of timber cut annually in Britain, but this amount is generally estimated at from 40 to 50 million c.f. This represents a cut of about 15 c.f. per acre per annum and, though during the early part of the nineteenth century the cut may have been greater than this, it was almost certainly less during the years before the war. During and immediately after the war itself a very large volume was cut, estimated at approximately 1,000 million c.f.[1] According to the Census of Production for 1924 the cut in that year for all purposes amounted to 55,985,000 c.f., of which 39,311,000 c.f. was timber of sawmill size.

Table XV shows an estimate of the total annual consumption of timber, in terms of standing volume, for each quinquennial period from 1844 to 1928. The imports are taken from Table XIII, and the home production has been estimated according to the data of the last paragraph. The population for each census year is also shown, and the population for intermediate years has been computed by interpolation. By this means the consumption per head of population, as shown in the last column, has been ascertained.

Per capita consumption. The *per capita* consumption in Britain rose almost continuously until 1901, when it was three times as great as in 1846. This was a period of rapidly rising population and very active urban development. It is well known that during the years preceding the war house-building fell short of the nation's needs, and this may account for the marked fall-off that occurred during those years in the *per capita* consumption of timber; but it is significant that, even with the post-war acceleration of house-building the 1901 level of *per capita* consumption has not been surpassed. This is partly due to slackness in the coal-mining industry, but is also in large measure to be attributed to the replacement of wood by metal and concrete in the construction of factories, office furniture, and

[1] R. L. Robinson, *Forestry*, vol. i, 1927, p. 1.

TABLE XV. *Consumption of timber per head of population in the British Isles (equivalent standing timber).*

Year.	*5-yr. aver. imports (corresponding standing vol.) Million c.f.*	*Annual cut in British Isles Million c.f.*	*Total consumed Million c.f.*	*Population millions.*	*Consumption per head of population c.f.*
1841				27·0	
1846	130	50	180	(27·4)	6·6
1851	150	50	200	27·7	7·2
1856	177	50	227	(28·5)	8·0
1861	229	50	279	29·3	9·5
1866	312	50	362	(30·6)	11·8
1871	374	50	424	31·8	13·3
1876	486	50	536	(33·5)	16·0
1881	484	50	534	35·2	15·1
1886	496	50	546	(36·7)	14·9
1891	599	50	649	38·1	17·0
1896	717	50	767	(40·0)	19·2
1901	802	50	852	42·0	20·3
1906	761	50	811	(43·7)	18·6
1911	774	50	824	45·4	18·1
1916	429	140	569	(46·1)	12·3
1921	576 [1]	100	676	42·8 [1]	15·8
1926	794 [1]	50	844	(43·6) [1]	19·3

for other purposes. Since the rate of increase in our population is rapidly declining and, indeed, is likely to become negative within the next fifteen years,[2] the demand for new houses is likely to fall off, and we cannot foresee any considerable rise in the national consumption of timber in the near future. On the contrary, a considerable fall in timber imports would not occasion surprise.

[1] Great Britain only.

[2] A. L. Bowley, 'Births and Population in Great Britain', *Econ. Journ.* xxxiv, 1924, p. 188.

IV

THE THEORY OF PRICE

The influence of timber prices on forest management: temporary and secular fluctuations in prices. Changes in prices: prices dependent on the demand for and supply of gold. Supply and demand: graph showing relation between price and demand: normal demand: graph showing relationship between price and supply: combinations of the two graphs: elastic and inelastic supply and demand. The purchasing power of money: the equation of exchange: factors which increase and decrease prices. An example from America: quantity theory. Price indices: Sauerbeck's price index: weighted and unweighted indices: use of arithmetic and geometric means.

The influence of timber prices on forest management. Foresters, as producers of timber, are dependent for their profits on the sale of timber, so that the price at which they can sell is a matter of great moment to them. In earlier days prices were fixed by custom, and the forest owner knew that there would be no great variation from year to year, but under modern industrial conditions this is seldom the case, and fluctuations in price are the rule rather than the exception. These fluctuations may be temporary, either annual fluctuations due to the seasons or the result of trade 'booms' and 'slumps', or changes may be cumulative and progressive over a period of half a century or more.

The price of timber in world-supplied markets, such as London, varies with the season, as much of the timber comes from ports which are closed during the winter; but these seasonal changes should have little influence on the price of standing timber in the forest. The price changes which chiefly influence foresters are (1) those due to alternate periods of depression and buoyancy in trade, and (2) secular changes which are caused either by changes in the value of money or growing scarcity in the world supply of wood. The first of these price changes influences the short term plans of the forest manager, viz. the amount of wood that he will elect to cut in the next few years; the second will affect his long term plans, the species he shall plant for future generations, their distance apart, or even whether he shall plant at all.

It is now well established that trade booms and depressions are the results of definite economic tendencies, and their causes have been studied in great detail, but even the best informed financier fails to prognosticate them with accuracy; in fact, could they be foretold their violence would be to a great extent modified. It is

consequently difficult for a forester to arrange his working plans with a view to short term price fluctuations. All he can hope to do at present is to make his plans sufficiently elastic to allow for increased fellings when the market is good.

Secular price changes affect forest finance very much more than trade booms and slumps because the production period in forestry is very long, namely, the length of a rotation. These secular changes are slow, but over a period of sixty or eighty years may be very large indeed, so that the prices which are obtained when the timber is cut may be widely different from the price of timber when the trees were planted. Some industrialists say that it is useless, when considering market conditions, to look forward more than twenty years, and in industries in which the final commodity is ready for sale within a year or two of the inception of its manufacture it is generally quite unnecessary. Thus a farmer who has the choice between sowing barley and wheat does not need to look forward more than a year or eighteen months for his market conditions, and the probable prices for the next five or ten years may determine such changes as the laying down of arable to grass or the ploughing up of pasture. The forester's crop, however, takes fifty, a hundred, or more years to mature, and any planting which he does now is done in the belief that the timber will be saleable at the end of the period. A rise of 1 per cent. per annum in the price of timber would cause the price to double in seventy-seven years, and if, as some writers think likely, this occurs with timber prices it will be of great benefit to planters or their successors. Thus the prospects of future prices must greatly influence forest practice, and the study of them is fundamental to forest finance.

Changes in prices. Prices are commonly expressed in terms of money, and if the price of an article is higher at one time than another, then more money has to be given in exchange for it. Now money can be regarded in two ways; it is both a medium of exchange and a standard of value. If before the war a man sold a book for a sovereign and with the sovereign bought a pair of shoes, the sovereign served as a useful medium for exchanging the book for a pair of shoes; it is most unlikely that the man who bought the book would have had a suitable pair of shoes to sell or that the shoemaker would have wanted the book. After the war he might have sold a similar book for £2 and with the £2 have bought a similar pair of shoes, and in this case the £2 would have served just the same purpose as the sovereign served before the war; it would have been the medium of exchange. But a difficulty arises when we come to use

money as a standard of value. The price of the book and of the pair of shoes was twice as high after the war as before, but would it be true to say that the value of either was twice as great? Might it not be truer to say that the value of the £1 after the war was a half of what it was before the war?

The issue is complicated by the fact that 'value' is a word with a very ill-defined meaning, and when we attempt to distinguish between price and value we find that there is no unit by which we can measure the latter. Price is readily expressed in the unit of money, the pound sterling, the dollar, mark, or franc, just as length can be expressed in yards, but for value there is no fixed standard. The difficulty can be obviated by postulating that the value, or, better, the purchasing power, of money varies in time, so that an intelligent study of changing prices must take into account changes in the purchasing power of money. How these changes can be measured will be explained in a subsequent section; here only the reasons for money having a purchasing value will be considered.

The study of prices is both technical and difficult. In recent expositions of the subject by forest economists entirely false conclusions have frequently been drawn because the writers have paid inadequate attention to the fundamental causes of price movements. It has been too readily assumed that a rise in the price of timber must have been due to a shortage in supply or a fall to over-production, whereas, the intricacies of price movements are such that a rise may have been occasioned by increased activity in the gold mines of South Africa, or a fall by a change in the policy of the Federal Bank of America. If foresters undertake to study price movements they must first familiarize themselves with the general theory of prices, and in this chapter the more elementary principles of this theory, in so far as it affects foresters, will be explained.

Currency has value either because it takes the form of a commodity which is in such demand that, whatever happened to the issuing authority, it would continue to be taken in exchange for other things, e.g. a sovereign; or because it takes the form of some token which can be exchanged for such a commodity by application to the issuing bank or government. Bank of England notes before the war belonged to the latter category. In either case the exchange value of £1 was the exchange value of about 113 grains Troy of fine gold. During the war gold was withdrawn from circulation and Treasury notes were issued the value of which was based on their number and the fact that they were legal tender. For a considerable period a pound note was worth less than 113 grains of gold, but the

gold standard has now been restored, since gold can be obtained at a fixed price if bought in certain minimum amounts.

Thus the exchange value of money is determined, in countries where the currency is based on a fixed gold standard, by the exchange value of gold. But the exchange value of gold is subject, like that of other commodities, to the laws of supply and demand. If a process were invented by which lead could be cheaply converted into gold, then the intrinsic value of gold would be greatly diminished and prices would rise enormously until some fresh standard for currency was established. If, on the other hand, the world's supply of gold were exhausted so that no new gold was mined the intrinsic value of gold would tend to rise and prices of other commodities to fall. The purchasing power of gold is, however, dependent on other things besides the amount of gold, and the subject must be discussed in a later section. In the meantime the laws of supply and demand must be explained.

Supply and Demand. The effect of supply and demand on the price of a commodity can be explained more easily if it is assumed, at the first, that the purchasing power of money for commodities as a whole remains constant; otherwise, conflicting elements enter into the determination of price and the whole question becomes much more complex.

It is generally recognized that, other things being equal, if the price of a commodity falls the demand increases. Thus if the price of bananas is reduced from 1*s*. 6*d*. a dozen to 1*s*. a dozen, many people will eat more bananas and many who did not buy them before will now buy them. If the price fell to 6*d*. a dozen still more would be sold, whereas if the price rose to 5*s*. a dozen very few indeed would cross the counter. This is fully realized in the markets, and if a glut of bananas occurs it is disposed of by lowering the price to such an extent that consumption is sufficiently increased. This relationship can be expressed by a curve, as in Fig. 3, so drawn that if P is any point on it the length of the line PN (the ordinate) represents the price and the length of ON (the abscissa) represents the amount consumed. If the price falls to P_1N_1 then the consumption rises to ON_1, and if the price rises to P_2N_2 the amount consumed falls to ON_2. If the price rose indefinitely the consumption would fall to nothing but would never become negative, and if the price fell to zero the consumption would become very large; so the shape of the curve in the graph represents fairly well the normal relation between price and consumption or price and demand. The consumption will vary according to the price, becoming greater if the

price falls but falling back to its original figure if the price again reaches the previous level. The whole curve expresses one rate of demand.

If conditions change, whether on account of new fashion, increased population, or other fluctuation, then a new relation may be set up between price and consumption. The demand may become such that at the price PN the consumption is greater than ON and rises to ON'; when the price is P_1N_1 then the consumption is ON_1'

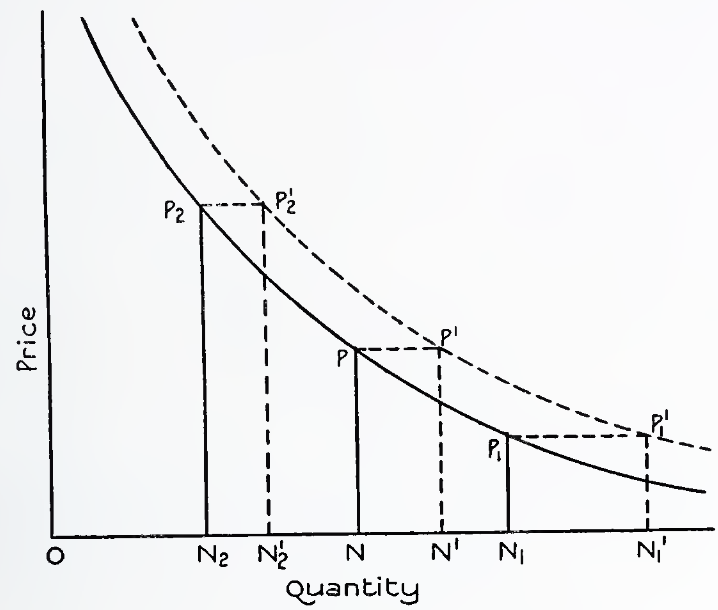

FIG. 3. The influence of price on demand.

and so on. In this case the old demand curve is replaced by the new one $P'P_1'P_2'$, which may be expected to be more or less parallel to the old one. There is a new rate of demand, and the change may be expressed as being a change in the 'normal demand'.

The consumption of some commodities is much more dependent on price than that of others. In general the consumption of any daily necessity, the cost of which does not loom very large in the family budget, is fairly constant and only slightly affected by changes in price. Such things are table salt or sewing cotton. The sale of luxuries, such as expensive fruit or motor-cars, is far more dependent on price, and any fall in price will greatly increase consumption. The demand for the latter class of goods is said to be 'elastic' and of the former 'inelastic', and such differences affect the shape of the demand curve. An elastic demand curve is rather flat while an inelastic one is steep.

The relation between supply and price can also be expressed by

a graph. Any increase in the market price of a commodity will stimulate production and so increase supply, and any lowering of price will tend to throw out of business the less efficient producers and consequently reduce supply.

In this graph (Fig. 4) ON is the quantity supplied if the price is PN, ON_1 if the price falls to P_1N_1, and ON_2 if the price rises to P_2N_2.

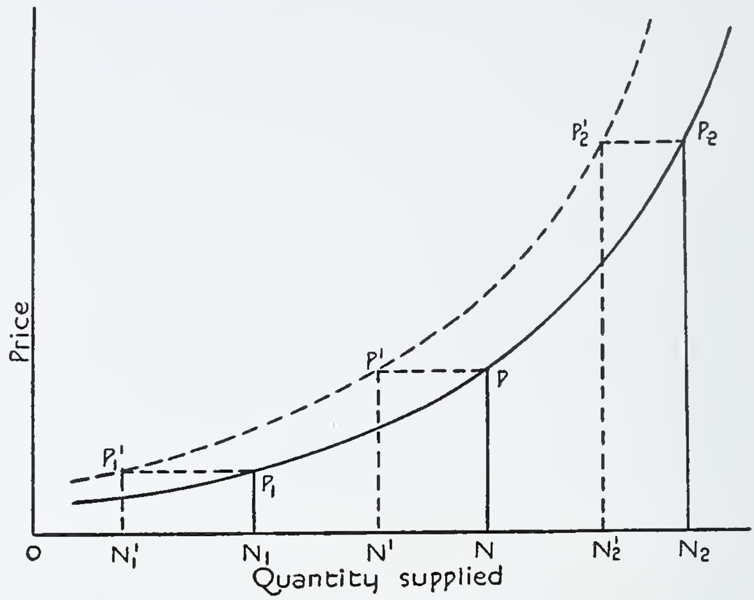

Fig. 4. The influence of price on supply.

It will be seen that the curve goes the other way from the demand curve. In this case, too, there may be a change in the 'normal supply', the quantity supplied at a given price being reduced, if the costs of production go up, as in the dotted curve in the figure; or if, owing to new inventions or new supplies of minerals or other causes, the cost of production is lowered, then the new normal supply curve will be below the old one.

Supply, like demand, may be elastic or inelastic. No change in price will alter the supply of genuine Raphael pictures or Stradivarius violins. A rise in the price of coal, on the other hand, makes it worth while to work mines which were previously lying idle; the more easily worked mines will then earn a considerable extra profit. In such cases the market price is not determined by the average cost of production but by the cost of production in the least profitable mines that it is still worth while to work. This has been called by Marshall the *marginal cost of production*, and the conception has important applications in the timber trade.

It is now possible to combine the curves of supply and demand as in Fig. 5. The supply curve and the demand curve cross at the point P, and if there is some change in the normal supply, say a glut of bananas in the West Indies, the supply curve will change to something like the dotted line. The price will fall to P_1N_1, and the quantity consumed will rise to ON_1. If at the same time there were

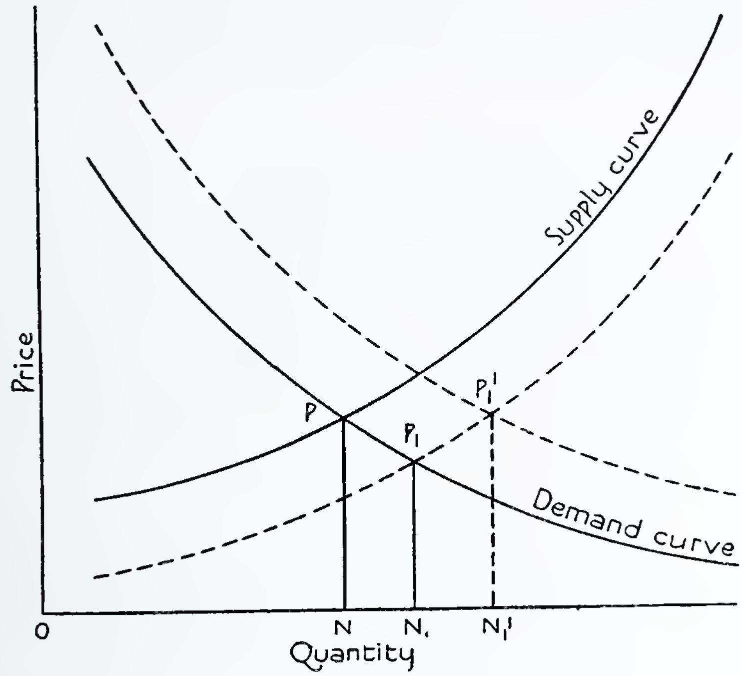

FIG. 5. The interaction of supply and demand.

an increase in demand, owing to a shortage of other fruit, there would be a new normal demand and the price might rise to $P_1'N_1'$ whilst the consumption increased to ON_1'.

This form of graph[1] has become the general method of representing the interaction of supply and demand and it is possible to trace,

[1] These graphs sometimes give rise to confusion for the following reason. The supply curve shows the increase in supply that is likely to follow a rise in price, i.e. the influence of price on supply. If, however, the supply is increased for some other reason (e.g. a good harvest) this will cause a fall in price. For this reason the curve associating the amount of an agricultural crop produced in a year and the price for the year shows a high price when production is poor and a low price when production is good, i.e. the curve follows the general form of the demand curve and not the supply curve. This will be easily understood since, if there is a large crop, the price has to fall until the demand is equal to the supply.

Such curves worked out for various crops in U.S.A. are given by Warren and Pearson, 'Interrelationships of Supply and Demand', *Cornell University Agricultural Exp. Stat. Bull.* 466, 1928.

by means of it, the various reactions in price to changes in the normal supply and demand.

It can be seen from the diagram that a fall in the price of a commodity from one year to the next may be due either to an increase in the normal supply or a decrease in the normal demand. If the former, it will be accompanied by an increase in the quantity sold, if the latter, by a decrease. Conversely a rise in price may be due to a reduction in normal supply accompanied by reduced consumption, or an increase in normal demand, accompanied by increased consumption.

A few general observations may now be made on the elasticity of the supply and demand for timber. In so far as the timber market is fed by the exploitation of virgin forests the supply is highly elastic. Any increase in the market price makes it worth while to extract timber from more and more inaccessible regions, and this greatly widens the range of economic lumbering. At the same time, the extraction of timber under modern conditions is only possible after the building of railways or improvements in river transport, and these generally take a year or more to accomplish. Also to effect any considerable increase in timber supply new sawmills may have to be erected and possibly improved dock facilities may have to be provided. Consequently, if market conditions are good and lumberers are working at full pressure there may be a lag of a year or more between a rise in price and any considerable increase in supply. In regulated forests with developed transport facilities, such as may be found in many parts of France and Germany, there is no inherent difficulty in felling a larger volume one year than another, but extended fellings cannot be continued over any long succession of years without depleting the forests. Where, as in Britain, timber has to be produced by planting it is clear that the supply can only be increased after a very long period of waiting.

Demand will depend chiefly on the activity in the industries which consume large quantities of timber. Of these industries the most important are the building of houses and factories, railway maintenance and extension, and coal mining. All forms of building are most active during periods of prosperity, and it does not appear that the demand for building material is greatly affected by fluctuation in price. If the demand fluctuates more or less independently of price we should expect to find prices rising very considerably in times of high consumption, and this is actually the case.

The prices of commodities for which the demand is elastic show much narrower price fluctuations than those of commodities for

which the demand is inelastic. Rubber, for example, has a comparatively inelastic market; it is used principally for motor-cars, but forms only a small part of the cost of a car. Very few people will be prevented from buying a motor-car because rubber is dear, and if there is a shortage in supply there will be active competition to buy what there is. This will cause a rapid rise in price, and in recent years the price per pound of rubber has fluctuated nearly thirty times as widely as the price of timber. The movements of timber prices suggest that demand for timber accommodates itself fairly readily to supply.

The Purchasing Power of Money. We have come to regard money as primarily a medium of exchange. Money has a certain amount of work to do in the year, namely, to facilitate all the exchanges of goods and services that take place in the year. It is quite easy to increase the amount of money, as most of the belligerent states found during and after the war, but this does not increase the wealth of the community. Its principal result is that there is more money to do the work and more units of money take part in each transaction. In other words prices rise.

The relation between the amount of money and prices is, in practice, much more complex than is indicated in the last paragraph. There is no doubt, however, that one of the factors influencing prices is the amount of gold in the world and the rate at which this amount is being increased. Any important finds of gold will tend to lower the purchasing power of money and raise the prices of all commodities other than gold. That this has actually happened in the past will be shown in the section on the history of price movements. If all money were in the form of gold then the total amount of money in the world would be limited by the total amount of gold. There are, however, several devices by which the amount of money, and substitutes which operate as money, greatly exceed the amount of gold. The first of these is bank notes, which are issued by a bank and are secured partly by gold stored and partly by securities held by the bank. The value of notes issued greatly exceeds the value of gold stored, and by this means the gold is made to do much more work than it could if it were issued as gold coins.

A still more important device which increases the amount of working currency in civilized countries is the system of private deposits at banks which can be withdrawn by cheque. A very large and steadily increasing proportion of money payments is made by cheques drawn on bank deposits, and a little consideration will make it clear that this must greatly reduce the demand for gold and bank

notes as a medium of exchange. Banks must always maintain a supply of coin and notes in order to meet the demands made on them, but this supply is very much less than the total of the deposits, so that our banking system provides a further dilution in the gold used in currency.

It is not only with the *amount* of currency that we are concerned. If each pound sterling, whether in the form of gold, note, or deposit subject to cheque, were used for payment only once a year then the total amount of money payments during the year would be limited to the amount of currency in existence. If each pound changed hands twice a year, then the total payments would be double the amount of currency. In practice each pound changes hands, on an average, much more than twice in a year, so that the total amount of money that passes in payments in a year very greatly exceeds the amount of currency; but it is clear that anything that expedites the passing of currency from one hand to another, anything, that is, that increases the velocity of circulation of money, increases the work that existing currency can do and will have an effect similar to that of increasing the amount of currency, i.e. it will reduce the purchasing power of money and raise prices.

This will become clearer by quoting the 'equation of exchange' which expresses the relation between the average amount of money in circulation in the community during the year (M), the average velocity of the circulation of money (V), the total quantity of each commodity sold during the year (Q, Q', Q'', &c.), and the average price of each commodity (p, p', p'', &c.). This equation is

$$MV = pQ + p'Q' + p''Q'' + \&c.$$ [1]

The right side of the equation represents the money value of all the money transactions in the year; the left side the total money in circulation multiplied by its average velocity of circulation.

Thus each of the following will *tend* to raise prices: (1) increased finds of gold; (2) increased note circulation; (3) a larger use of cheques, drawn on bank deposits, for the making of payments; (4) any increase in the velocity of circulation of money, whether due to one or other of the above or to improved postal and telegraph facilities or to any other cause. As these causes are operating in greater and greater degree as time goes on it might appear that prices must inevitably rise continuously. However, they are, in part at least, counteracted by other factors which tend to reduce prices, and these must now be considered.

[1] Irving Fisher, *Purchasing Power of Money*, 1920.

The factors tending to raise price, enumerated in the last paragraph are all factors which tend to increase MV in the equation on p. 62. If this equation is true, and if MV is increased while Q, Q', &c., remain constant, then some, or all of p, p', &c., must increase. On the other hand, if the amount of the commodities sold (Q, Q', &c.) increases as rapidly as MV then the prices will remain about the same; and if Q, Q' increase more rapidly than MV then the average of p, p' must fall. In other words, prices will only rise if the amount of money in circulation, multiplied by its velocity of circulation, rises more rapidly than the total amount of yearly transactions.

During a part of the nineteenth century, from about 1873 to 1895, there was a definite shortage of gold which is ascribed partly to there having been no great finds of gold during the period and partly to the adoption by many continental countries[1] of a gold standard for currency. These countries required large consignments of gold at a time when the mines were not productive, and this had the effect of greatly increasing the purchasing power of money and reducing prices. The exploitation of the South African goldfields, which began in the nineties, had a startling influence on prices which reached their lowest point in 1896, and subsequently rose rapidly.

Apart from the increasing demand for gold, which is due to fresh countries adopting a gold standard, there is a great increase in the use of currency in each country due to (1) rise in population, and (2) increased trade and increased wealth per head of population. There may also be other circumstances operating in particular cases which temporarily increase the use of currency.

An example from America. The equation on p. 62 should be capable of expression in figures which might furnish it with a statistical verification. Such a verification has been attempted by Irving Fisher[2] for the total trade of the U.S.A. from 1896 to 1909; here, however, no recapitulation of the argument will be given, but only his figures for the first and last years of the period as a demonstration of the rapidity with which changes occurred during this time. For this purpose the equation must be stated in the new form:

$$MV+M'V' = PT$$

where M is the total money (coin and bank notes) in circulation; V, the velocity of circulation of this money, i.e. the average number of times it is used for payment in the year; M', the volume of bank

[1] Germany, 1871–3; Scandinavia, 1873; Netherlands, 1875–6; Austria, 1892, &c.

[2] *Purchasing Power of Money.*

deposits subject to cheque, and V', its velocity of circulation; T is a figure *representing* the volume of trade; for 1909 it is the actual estimated money turnover; for 1896 it is an estimate of the money turnover that there would have been if the prices had been the same as in 1909. The figures for T for the years 1896 and 1909 are thus proportional to the quantities sold, not to the total amounts paid. P is a price index, the average prices for 1909 being equated to unity.

	M *Billions of dollars.*	V	M' *Billions of dollars.*	V'	T *Billions of dollars.*	P	$MV+M'V'$	PT
1896 . .	0·87	19	2·68	36	209	0·63	113	132
1909 . .	1·63	22	6·75	54	399	1·00	399	399

The agreement between $MV+M'V'$ and PT in 1909 arises from the method of calculation. The approximate agreement (there is an error of about 16 per cent.) in 1896 is not due to this cause, and is a remarkable verification of the quantity theory of money. The figures are interesting in themselves and show the extraordinary predominance of cheques on bank deposits as a means of making payments. It must not be forgotten, however, that these bank deposits are in part secured by stored bullion, and unless this restriction is abated the deposits cannot grow indefinitely without the introduction of more and more gold into the coffers of the banks.

Price indices. When it is said that prices as a whole have risen or fallen this is clearly a generalized statement. The price of one commodity may rise while that of another is falling, and when the movements of prices are considered as a whole it is necessary to take an average of the prices of all commodities, or as many as possible. The simplest method is that followed by Sauerbeck in 1886.[1] Sauerbeck estimated the wholesale prices of 43 to 45 articles for the years 1846 to 1885. For each article he put the average of the annual prices for the years 1867 to 1877 equal to 100 and expressed the price each year for each article as a percentage of this average. This price is the 'relative price' of the article for the year concerned. All the relative prices for each year were added up and the sum was divided by the number of articles to give the index number for the year.

As an illustration of this method we will consider the price index number for 1885 based on three articles only. The average price during the eleven years 1867–77 for English wheat was 54*s.* per

[1] 'Prices of Commodities and Precious Metals', *Journ. Roy. Stat. Soc.*, vol. xlix, 1886, p. 581. The annual index numbers were contributed by Sauerbeck to this journal till 1915 when they were continued by the editor of the *Statist*.

quarter, for Scotch pig iron 69*s.* per ton, and for River Plate dry hides 9*d.* per pound. In 1885 the respective prices of these articles were 33*s.*, 42*s.*, and $8\frac{3}{4}$*d.* If all the prices for 1867–77 are equated to 100 and the prices for 1885 are raised proportionally the average for the two periods works out as follows:

	1867–77 *price.*		1885 *price.*	
	Actual.	*Relative.*	*Actual.*	*Relative.*
English wheat	54*s.*	100	33*s.*	61
Scottish pig iron	69*s.*	100	42*s.*	61
R. Plate hides	9*d.*	100	$8\frac{3}{4}$*d.*	97
	mean	100		73

Thus it appears that prices in 1885 were 27 per cent. lower than in 1867–77. In the above example only three commodities were considered, but the accuracy of the method depends on introducing as many commodities as possible.

This method, although of great historical importance, is unsatisfactory in many respects. In the first place it gives equal importance to commodities which play very unequal parts, whether in wholesale trade or in household economy. Thus silk carries the same weight as coal, though a doubling in the price of the former would affect the cost of living very much less than a doubling in the price of the latter. The error due to this can be largely obviated by weighting the prices of certain commodities, say by counting the relative price of coal five times over whilst the relative price of leather is only counted once. By this means a doubling in the price of coal would affect the price index five times as much as a doubling in the price of leather. Index numbers calculated in this way are called 'weighted price index numbers'.

Next, the arithmetic mean is not a suitable average for calculations of this sort, as can be shown by an example. Let us compare two years, *A* and *B*, and suppose that the prices of three different items, *P*, *Q*, *R*, were respectively in the year *A*, 6*d.*, £5, and 10*s.*, and in the year *B*, 6*d.*, £2 10*s.*, and £1. If we take the year *A* as a base the price of each item in that year is raised to 100 and the prices for *B* are raised proportionately. Then the relative prices of the three items will be:

	Year A.	*Year B.*
Item *P* . .	100	100
Item *Q* . .	100	50
Item *R* . .	100	200
Index No.	$\frac{300}{3} = 100$	$\frac{350}{3} = 117$

It appears from this that the prices were 17 per cent. higher in the year B than in the year A.

If, however, we took the year B as the base year and calculated the index number for the year A in relation to it we should get the following result:

	Year B.	*Year A.*
Item P . .	100	100
Item Q . .	100	200
Item R . .	100	50
Index No.	$\frac{300}{3} = 100$	$\frac{350}{3} = 117$

From this it appears that prices were 17 per cent. higher in the year A than in the year B.[1]

This error can be partly obviated by taking the geometric mean instead of the arithmetic mean, since

$$\sqrt[3]{100 \times 200 \times 50} = \sqrt[3]{100 \times 100 \times 100} = 100$$

which would show the same price level for the two years.

Another difficulty arises from the fact that in the course of years entirely new items may come to play an important part in trade, such as motor-cars during this century, whereas other articles become obsolete.

The making of index numbers is gradually becoming more and more specialized,[2] but enough has been said to show that great caution has to be used in employing Sauerbeck's or other early index numbers.

[1] Examples of this type of error are given by A. L. Bowley, *Prices and Wages in the U.K.*, 1914–20. Professor Bowley considers that this cause of error was not of great importance until the war.

[2] See Irving Fisher, *The making of Index Numbers.*

V

THE PRICE OF TIMBER

History of price movements; influence of gold supply. Secular movements in the price of timber: Board of Trade Returns: Sauerbeck's index number and timber prices: relative, and corrected relative, prices for hewn wood, and sawn and split wood: divergence between price movements of hewn wood and sawn and split wood: price movements of sawn and split fir: price movements of teak. Movements of timber prices in U.S.A. Quotation from the Capper Report. Price Movements in Germany. Relation of price of standing timber to price of sawn timber.

History of price movements. Little definite information about the movements of prices until the beginning of the nineteenth century is obtainable. Opinions differ as to the stability of prices during the Middle Ages, but there is no doubt that throughout the greater part of Europe prices advanced very rapidly during the sixteenth century, at the end of which, according to Leber's estimate, prices were three times as high as at the beginning. This rise was the result of the introduction of large quantities of gold following the discovery of America and the subsequent conquest of Mexico, Peru, and other parts of the mainland. The price advance first affected Spain and then Holland, but it spread gradually to all other countries. The period from 1600 to 1800 was characterized by fluctuations which tended to obscure the constant tendency of prices to rise.

The movements in prices from 1846 onwards can be seen in column A of Table XVI, p. 70, and the following notes on these movements are taken from Layton.[1] The first few years down to 1849 terminate a period of falling prices which had been nearly continuous since the Napoleonic wars. But in 1848 gold was discovered in California, and in 1849 in Australia, and in seven years the gold output of the world increased sixfold. To this is mainly due the sharp rise in prices to 1854. Thereafter, the greatly increased trade absorbed the gold supply sufficiently to keep prices constant until the great trade boom of the early seventies caused a temporary rise. The period 1874 to 1896 was characterized by almost continuously falling prices, and during this period a fall of over 40 per cent. in the price index was recorded. It was a time of constant or slightly falling gold output, but Germany and U.S.A. and some other countries demonetized silver and adopted a gold basis. The growth in population and industrial developments enormously increased the demand for currency; and, though there was a very great increase in the use of banking facilities which aug-

[1] W. T. Layton, *An Introduction to the Study of Prices*, Macmillan, 1920.

mented currency and accelerated the velocity of exchange, these failed adequately to meet the increased demand, so that prices fell to an alarming extent.

The rise in prices from 1896 to the war was nearly as rapid as the previous fall. This rise is associated with two developments in the gold supply, one, the discovery of very rich deposits in South Africa, the other, improvements in the processes of gold extraction in other areas; and the result of these developments was a rise in the world production of gold from 177 tons in 1890 to 712 tons in 1910.

The rise in prices during the war and the subsequent fall were due to special reasons which it is unnecessary to discuss here; but it is reasonable to suppose that, had the war not occurred, prices would now have been considerably higher than in 1913 though not quite as high as they are to-day.

Secular movements in the price of timber. So far the changes in prices that have been considered have referred to average prices as calculated by index numbers. No attention has been paid to particular commodities, the prices of which may have appreciated or depreciated in a very different manner from prices in general. Thus the price of grain and flour varies with the crop yields from year to year; the price of motor-cars tends to fall continuously with advances in engineering skill and mass production.

In this section we are concerned with the particular case of timber, and our object is to ascertain whether the prices of timber have been, in general, rising or falling during the period for which we have statistical evidence. Figures have to be obtained from whatever statistics are available, and the longest consecutive series is recorded in the Board of Trade Returns[1] and refers to the c.i.f.[2] import amounts and values at British ports.

The chief difficulty in using these figures arises from the frequent changes in the categories into which timber imports have been divided. Thus from 1843 to 1851 quantities of timber imported are recorded in loads for (1) timber not sawn or split, (2) timber sawn or split, (3) staves. In 1852 a category was distinguished for mahogany (in tons), and in 1879 an entry appears under 'unenumerated' covering a small but appreciable quantity of expensive woods. In 1891 the number of categories was extensively enlarged,

[1] (1) Statistical Abstract for the United Kingdom.
(2) Annual Statement of the Trade of the United Kingdom.
(Both published annually.)
(3) Report of wholesale and retail prices in the United Kingdom, 1902, with comparative Statistical Tables for a series of years. Parliamentary Report, 1903.

[2] Cost, insurance, freight, i.e. price at the wharf side in British ports.

'hewn' timber being divided into fir, oak, teak, and unenumerated; sawn and split into fir and unenumerated. In 1901 pit timber was distinguished from other 'hewn fir' and in 1920 no less than twenty-two categories of timber were recognized. From 1926 onwards the number of categories has been reduced, and walnut, oak, and teak are no longer distinguished.

Until 1854 the Board of Trade Returns quoted quantities, but not values. These early returns are, therefore, of no use for the computation of prices. Sauerbeck,[1] with the object of computing his price index, inserted ascertained prices of 'Canadian yellow pine' from 1846 to 1853, and 'computed real values' from 1854 to 1870. From 1871 onwards the values declared by the Board of Trade have been used. Since Sauerbeck's death this series has been continued by the Editor of the *Statist*,[2] and the complete series, both for hewn wood, and sawn and split wood, are quoted, together with Sauerbeck's price index, in Table XVI.

The table is constructed as follows. Column B gives Sauerbeck's price index number for each year, and Column C gives the c.i.f. import price of hewn timber. The mean of the prices for the period 1867 to 1877 (the base period for Sauerbeck's index) is 60·3*s.*; in Column D this figure is raised to 100 and others proportionately; this is the 'relative price' for each year. The figures in Column E are obtained by dividing the relative price for each year by the price index number for that year and multiplying by 100; this is the 'corrected relative price'. If the prices of timber moved exactly proportionately to the index number Column E would be 100 throughout; the figures in this column actually represent the relative prices of timber as they would have been if the purchasing power of money had remained constant throughout. Columns F, G, H repeat columns C, D, E for sawn and split timber. The figures in italics are quinquennial averages.

From this table it appears that the actual price of hewn wood was rising from 1848 to 1854, from which date it fell more or less continuously till the early nineties and afterwards remained nearly constant till the war. But when corrections are made for changes in the purchasing power of money it appears that the fall in real price (i.e. corrected relative price) was very nearly continuous from 1852 till 1913, and that the corrected post-war price is even lower than the pre-war price.

[1] *Journ. Roy. Stat. Soc.*, xlix, 1886, p. 581, and subsequent articles.

[2] *Journ. Roy. Stat. Soc.*, lxiii, p. 92; lxviii, 1905, p. 138; lxxxviii, 1925, p. 260; xci, 1928, p. 394.

TABLE XVI. *Price movements of 'Hewn Wood' and 'Sawn and Split Wood' corrected against Sauerbeck's index number.*

		Hewn Wood.			*Sawn and Split Wood.*		
Date.	*Sauerbeck's Index No.* 1867–77 = 100	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price.*	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price*
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1846	89	75	124	139	—	—	—
7	95	75 *66*	124	130 *130*	—	—	—
8	78	55	91	117	—	—	—
9	74	60	99	134	—	—	—
1850	77	55	91	118	—	—	—
1	75	60	99	132	—	—	—
2	78	75 *71*	124	159 *138*	—	—	—
3	95	80	133	140	—	—	—
4	102	87	144	141	74	136	133
1855	101	84	139	138	72	133	132
6	101	80	133	132	63	116	115
7	105	70 *74*	116	111 *124*	55 *59*	101	96 *110*
8	91	65	108	119	48	88	97
9	94	69	114	121	57	105	112
1860	99	74	123	124	62	114	115
1	98	76	126	128	58	107	109
2	101	76 *74*	126	125 *121*	58 *58*	107	106 *106*
3	103	72	119	115	57	105	102
4	105	72	119	113	57	105	100
1865	101	67	111	110	58	107	106
6	102	61	101	99	55	101	99
7	100	58 *62*	96	96 *103*	52 *53*	96	96 *98*
8	99	61	101	102	51	94	95
9	98	65	108	110	51	94	96
1870	96	65	108	112	52	96	100
1	100	56	93	93	46	85	85
2	109	58 *62*	96	88 *99*	49 *55*	90	83 *96*
3	111	65	108	97	62	114	103
4	102	64	106	104	65	119	117
1875	96	57	95	99	56	103	107
6	95	58	96	101	56	103	108
7	94	56 *52*	93	99 *95*	58 *53*	107	114 *106*
8	87	49	81	93	50	92	106
9	83	42	70	84	43	79	94

		Hewn Wood.			*Sawn and Split Wood.*		
Date.	*Sauerbeck's Index No.* 1867–77 = 100	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price.*	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price.*
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1880	88	49	81	92	52	96	109
1	85	51	85	100	50	92	108
2	84	52 *50*	86	102 *101*	52 *50*	96	114 *110*
3	82	52	86	105	48	88	107
4	76	48	80	105	46	85	112
1885	72	48	80	111	45	83	115
6	69	43	71	103	43	79	114
7	68	38 *43*	63	93 *102*	42 *45*	77	113 *115*
8	70	41	68	97	44	81	116
9	72	47	78	108	49	90	125
1890	72	44	73	101	46	85	118
1	72	40	66	92	43	79	110
2	68	40 *40*	66	97 *96*	44 *44*	81	119 *118*
3	68	38	63	93	43	79	116
4	63	36	60	95	44	81	128
1895	62	37	61	98	42	77	124
6	61	40	66	108	44	81	133
7	62	41 *40*	68	110 *104*	47 *46*	86	139 *132*
8	64	42	70	109	47	86	134
9	68	40	66	97	49	90	132
1900	75	41	68	91	56	103	137
1	70	39	65	93	52	96	137
2	69	39 *39*	65	94 *92*	51 *52*	94	136 *137*
3	69	39	65	94	54	99	143
4	70	36	60	86	51	94	134
1905	72	38	63	87	51	94	130
6	77	40	66	86	55	101	131
7	80	40 *38*	66	82 *83*	57 *54*	105	131 *132*
8	73	36	60	82	53	97	133
9	74	34	56	76	54	99	134
1910	78	36	60	77	57	105	135
1	80	38	63	79	57	105	131
2	85	41 *39*	68	80 *79*	60 *60*	110	129 *134*
3	85	40	66	78	63	116	136
4	85	41¾	69	81	64½	119	140

		Hewn Wood.			*Sawn and Split Wood.*		
Date.	*Sauerbeck's Index No.* 1867–77 = 100	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price.*	*Price per load in shillings.*	*Relative Price* 1867–77 = 100	*Corrected Rel. price.*
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1915	108	$58\frac{7}{8}$	98	91	$94\frac{1}{4}$	173	160
6	136	$82\frac{1}{8}$	136	100	$148\frac{1}{2}$	273	201
7	175	$97\frac{5}{8}$ *97*	162	93 *98*	210 *191*	386	220 *210*
8	192	$107\frac{3}{8}$	178	93	271	499	260
9	206	$137\frac{1}{2}$	228	111	$232\frac{1}{2}$	428	208
1920	251	$119\frac{4}{5}$	199	79	$261\frac{7}{8}$	481	192
1	155	$68\frac{3}{4}$	114	74	$156\frac{13}{16}$	288	186
2	131	$46\frac{5}{8}$ *67*	77	59 *67*	$117\frac{1}{2}$ *158*	216	165 *181*
3	129	48	80	62	$131\frac{1}{8}$	242	188
4	139	$49\frac{4}{5}$	83	60	122	224	176
1925	136	$47\frac{15}{16}$	79	58	$122\frac{15}{16}$	226	166
6	126	$48\frac{29}{32}$ *47*	81	64 *61*	107 *112*	197	156 *161*
7	122	$45\frac{7}{16}$	75	61	$107\frac{9}{16}$	198	162

The prices of sawn and split wood behaved very differently. The actual price fell nearly continuously from 1854 to 1895, and thereafter rose nearly continuously till the war. But the corrected figures show that real prices were falling from 1854 till 1872, from which date they rose till 1897, and thereafter remained nearly constant till the war. There was a pronounced rise during the war, and, though prices have fallen very much since, the corrected relative price is higher now than at any time before the war. The real price of hewn wood shows a nearly continuous fall in price of 0·9 per cent. per annum, whereas the real price of sawn and split wood shows a nearly continuous rise from 1870 to 1914 of 0·8 per cent. per annum. How are we to reconcile this divergence?

The average price of hewn wood has in the course of years become more and more dominated by the price of pit timber. In 1901, the first year in which this form of timber was distinguished from 'other hewn fir', it formed 68 per cent. of all the imports of hewn wood; in 1913 it represented 79 per cent., and in 1928 87 per cent. As the price of pit timber is less than half that of the remaining hewn wood, its growing importance has necessarily had a depressing effect on the average prices of hewn wood. Thus the fall in the real price of hewn wood may, at least in part, be attributed to a lowering in quality. More and more of the better class timber is being sawn before import, and we are approaching a state at which the only

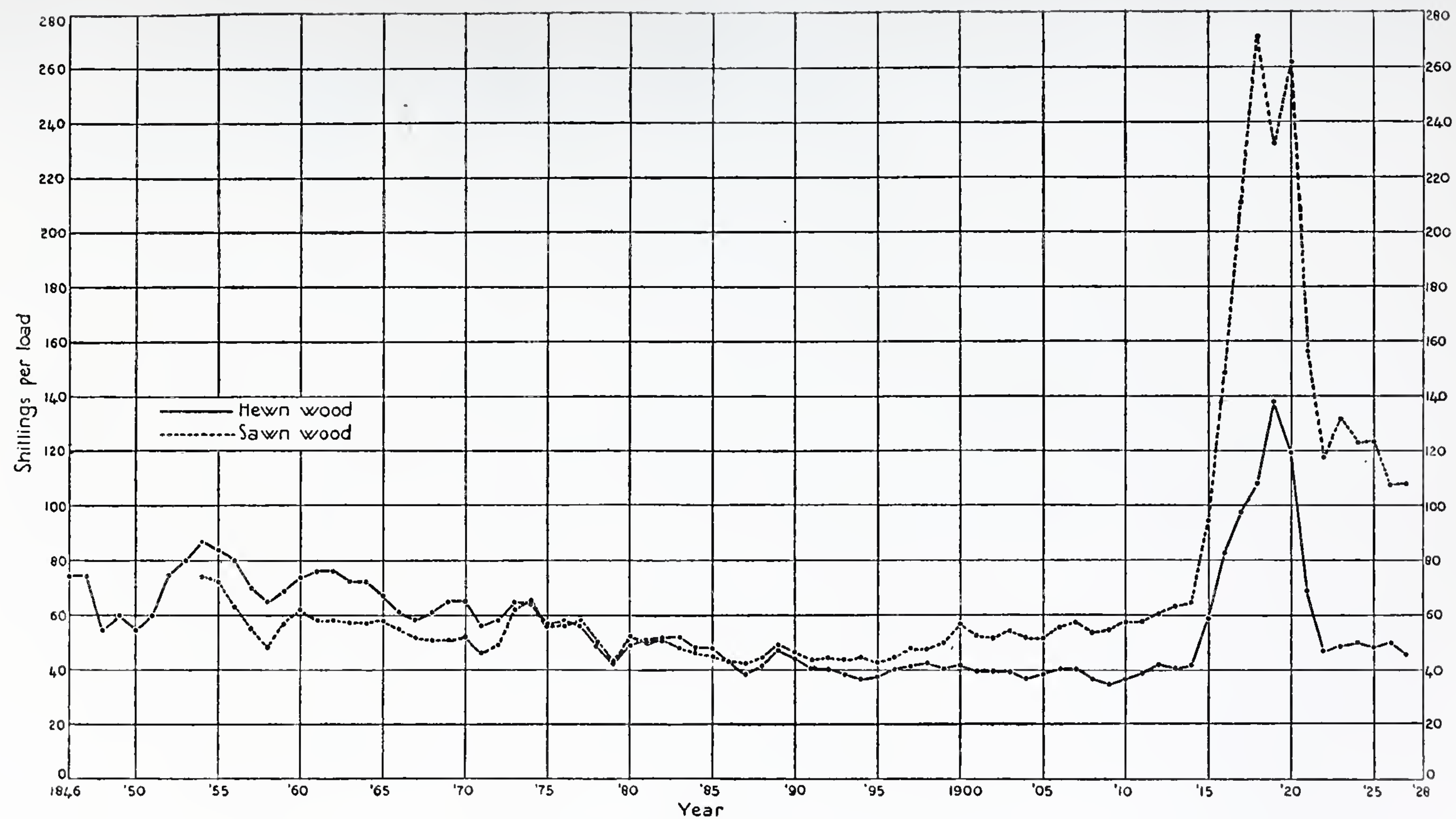

Fig. 6: Price movements of British imports of hewn wood and sawn and split wood in shillings per load from 1846–1927.

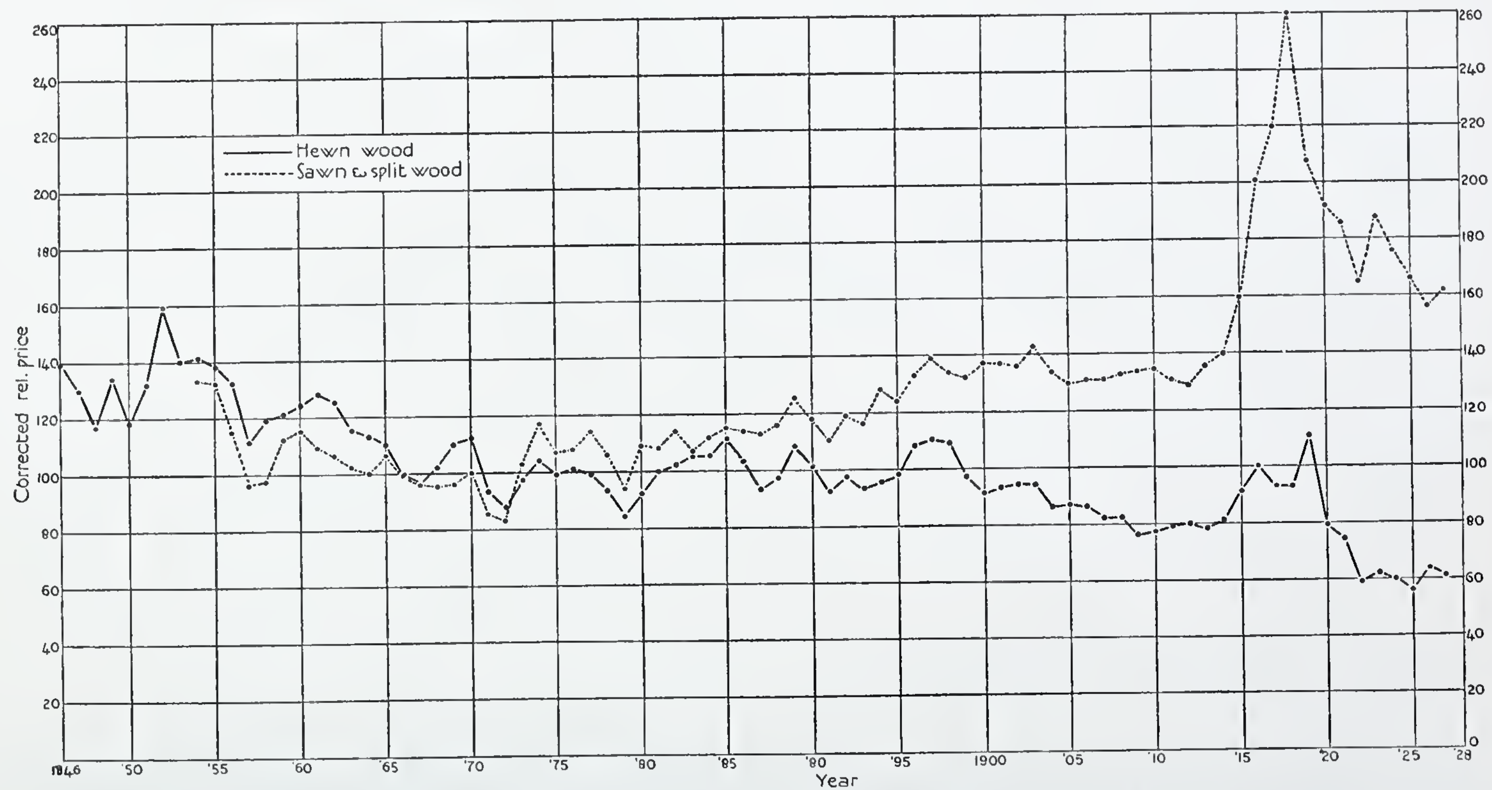

FIG. 7. Corrected relative prices (1867–77 = 100) for hewn wood and sawn and split wood from 1846–1927

timber which is not sawn before being sent to this country is round pit props which do not need to be sawn.

It must not be inferred from this that the average quality of sawn and split timber has risen; indeed, there is reason to think that the average quality of this has also fallen, since medium qualities which previously arrived in the round are now sawn in the countries of export. It thus appears that the figures given in Table XVI do not indicate very clearly the real changes in timber prices, and we are forced to content ourselves with movements over shorter periods for which more clearly defined categories are distinguished.

In Table XVII figures are given of the Board of Trade Wholesale Price Index Number and the c.i.f. prices of imported 'sawn and split fir'. This category is much more significant for the present purpose than that of 'sawn and split wood' because it includes coniferous wood only; but since 1913 this category has again been subdivided, and 'sleepers' and 'planed or dressed' wood have been distinguished. The latter classes are not necessarily confined to conifers but, in actual practice, conifers are overwhelmingly predominant in them, and, for the sake of consistency, it is far more accurate to include them with conifers than to exclude them. There is no doubt that the quality of this timber has varied, but two tendencies have been operating which have served in some measure to neutralize each other.

TABLE XVII. *Price movements of imported 'Sawn and Split Fir' and Teak. Corrected against the Board of Trade Wholesale Price Index Number.*

		Sawn and Split Fir.			*Teak.*		
Date.	*Bd. of Trade Index No. 1900 = 100.*	*Price per load in £.*	*Relative Price 1900 = 100*	*Corrected Rel. Price*	*Price per cub. ft. shillings.*	*Relative Price 1900 = 100*	*Corrected Rel. Price*
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1871	135·6	2·32	83	61	—	—	—
2	145·2	2·50	90	62	—	—	—
3	151·9	3·15	113	74 *70*	—	—	—
4	146·9	3·36	120	82	—	—	—
1875	140·4	2·86	102	73	—	—	—
6	137·1	2·88	103	75	—	—	—
7	140·4	2·95	106	76 *72*	—	—	—
8	131·1	2·57	92	70	—	—	—
9	125·0	2·25	81	65	—	—	—

		Sawn and Split Fir.			Teak.		
Date.	*Bd. of Trade Index No. 1900 = 100.*	*Price per load in £*	*Relative Price 1900 = 100.*	*Corrected Rel. Price*	*Price per cub. ft. shillings.*	*Relative Price 1900 = 100.*	*Corrected Rel. Price*
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1880	129·0	2·66	95	74	—	—	—
1	126·6	2·59	93	74	—	—	—
2	127·7	2·66	95	74 *73*	—	—	—
3	125·9	2·49	89	71	—	—	—
4	114·1	2·34	84	74	—	—	—
1885	107·0	2·32	83	78	—	—	—
6	101·0	2·20	79	78	—	—	—
7	98·8	2·10	75	76 *80*	—	—	—
8	101·8	2·24	80	79	—	—	—
9	103·4	2·50	90	87	—	—	—
1890	103·3	2·35	84	81	—	—	—
1	106·9	2·14	77	72	4·11	83	78
2	101·1	2·18	78	77 *78*	4·27	86	85 *83*
3	99·4	2·14	77	77	4·12	83	83
4	93·5	2·17	78	83	4·20	84	90
1895	90·7	2·09	75	83	3·87	78	86
6	88·2	2·20	79	90	4·25	85	96
7	90·1	2·35	84	93 *90*	4·66	94	104 *99*
8	93·2	2·35	84	90	4·71	95	102
9	92·2	2·42	87	94	4·85	97	105
1900	100·0	2·79	100	100	4·98	100	100
1	96·7	2·56	92	95	4·85	97	100
2	96·4	2·55	91	94 *96*	4·92	99	103 *104*
3	96·9	2·66	95	98	5·20	104	107
4	98·2	2·51	90	92	5·37	108	110
1905	97·6	2·50	90	92	5·75	115	118
6	100·8	2·73	98	98	6·20	124	124
7	106·0	2·81	101	95 *93*	6.36	128	121 *122*
8	103·0	2·60	93	90	6.47	130	126
9	104·1	2·67	96	92	6·38	128	123
1910	108·8	2·79	100	92	6·50	130	119
1	109·4	2·81	101	92	6·54	131	120
2	114·9	2·95	106	92 *94*	6·73	135	117 *122*
3	116·5	3·13	112	96	7·36	148	127
4	117·2	3·20	115	98	7·53	151	129
1915	143·9	4·67	167	116	9·22	185	128
6	186·5	7·41	266	143	8·83	177	95
7	243·0	10·46	375	154 *145*	11·61	233	96 *114*
8	267·4	13·50	484	181	16·38	329	123
9	296·3	10·82	388	131	18·77	377	127

		Sawn and Split Fir.			Teak.		
Date.	Bd. of Trade Index No. 1900 = 100.	Price per load in £.	Relative Price 1900 = 100.	Corrected Rel. Price	Price per cub. ft. shillings.	Relative Price. 1900 = 100.	Corrected Rel. Price
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1920	358·2*	11·85	425	119	21·55	433	121
1	229·9*	7·22	259	113	15·01	301	131
2	185·0*	5·37	192	104 *110*	11·11	223	120 *114*
3	185.1*	5·76	206	111	9·78	196	106
4	193·7*	5.44	195	101	9·00	181	93
1925	185·3*	4·98	178	96	not quoted	—	—
6	172·6*	4·68	168	97	"	—	—
7	164·4*	4·78	171	104 *100*	"	—	—
8	163·5*	4·77	171	105	"	—	—

Notes.—(1) Board of Trade Wholesale Index Number up to 1919 is quoted from *Board of Trade Labour Gazette*, January 1920, p. 5: from 1920 onwards the *Board of Trade Journal and Commercial Gazette*, 10 Oct. 1924, 12 Jan. 1928, and 19 Jan. 1929. For the later years (*) quotations are given on a basis of 1913 as 100, and these figures have been corrected by proportional reduction to a basis of 1900 = 100.

(2) The prices for 'sawn and split fir' from 1871 to 1902 are quoted from 'Report on Wholesale and Retail Prices in the U.K.', Parl. Rep. 1903. Subsequent figures are calculated from Annual Reports and include sleepers and planed or dressed wood.

There has been a reduction in the average size of the timber, and more knotty timber is now accepted than formerly; at the same time a greater proportion of the timber is now imported in a worked state, not only sawn but planed, and in some cases, shaped. Thus, whilst the average quality of the timber itself has become poorer, more work has been spent on it before importation.

The figure for sawn and split fir is probably the best general guide through the intricacies of price changes that can be obtained from the Board of Trade Returns, but a detailed study of price changes in timber from separate countries should supply far more exact information.

The quinquennial averages for the corrected relative prices of 'sawn and split fir' show the same general movements of prices as for 'sawn and split wood'. Real prices rose continuously from 1871/74 till 1900/04, reaching a maximum in 1900. Thereafter, they remained nearly constant till the war when a prominent rise occurred followed by a prominent fall. The real price is higher now than before the war, but the average for 1925/28 was the same as the real price in 1900.

If a timber shortage occurs it will be reflected in a rise in real

prices. The evidence before us appears to show that from 1871 to 1900 timber was becoming increasingly difficult to obtain, but that, since then, there has been no further increase in the real cost of extraction, sawing, and freightage. This is a somewhat unexpected result, and, though its causes have not yet been sufficiently analysed, two factors are worthy of note. One is the decrease in our imports from Norway, which is not only nearer to Britain than the Baltic but at one time contained a large amount of easily accessible timber. This factor may account, in some measure, for the rise in prices up to 1900. The other factor is the extensive development of the saw-mill industry since 1900; many more mills have been erected, especially in Finland, and the competition between shippers has become so keen that only well-managed companies can survive. This must have had an important influence in keeping prices down.

The real price of teak, which is shown in Table XVII for the years 1891 to 1924, has moved in a curious manner. It shows a rapid rise from 1891 to 1908, but from that time it has tended to decline. The reasons for this will require a special study for their elucidation.

Movements of timber prices in U.S.A. Particular interest attaches to the statistics of price movements in the United States of America because all the stages from a superfluity of timber to a serious shortage can be traced in a few years. So improvident have the Americans been in the use of their timber supplies that with a comparatively small population to the square mile they have devastated nearly all the forest areas on the eastern side of the country, the Southern states have been practically worked out, and they have now to rely principally on the stores of timber, which indeed are very large, on the west side of the Rocky Mountains. The rise in the price of timber in the Eastern states is thus chiefly due to the great distances over which timber has now to be carried. The following extract from one of the most illuminating government reports that has ever been written on the subject of timber supplies[1] presents a picture of the rise in timber prices in U.S.A.

'Eastern softwood markets. Table XVIII shows the lumber prices in eastern markets at five-year intervals from 1840 to 1910 and yearly from 1910 to 1920. The prices are computed throughout on a gold standard to eliminate the distortion resulting from depreciated values during the paper-currency period.

'While a great variety of factors have influenced lumber prices

[1] *Timber Depletion, Lumber Prices, Lumber Exports, and Concentration of Timber Ownership.* Washington, Govt. Printing Office, 1920. (The 'Capper Report'.)

a succession of price levels with sudden transitions corresponding to important shiftings of the field of supply may be readily discerned. There has been much price fluctuation in the softwoods, but in every instance price declines have ultimately been regained and new levels have been established. The underlying cause has been the widening distance between the sawmill and the consumer of its product. . . .

'Between 1840 and 1860 average prices of softwood lumber in the eastern markets followed quite closely the average price of all commodities. The lumber was principally white pine from New York, New England, and Pennsylvania. The average value of upper grades in the wholesale trade fluctuated between 20 and 30 dollars, centring about 25 dollars per thousand feet, while material of average quality sold fairly uniformly at 10 to 11 dollars. Transportation costs were about 1 dollar per thousand. About 1850 white pine from the Lake States began to filter through to the Atlantic seaboard, and by 1860 Chicago had replaced Albany, N.Y., as the leading lumber distributing centre in the world. The increase in volume of the more distant Lake States timber entering the eastern market from then on was accompanied by a price advance in upper grades from 24 dollars in 1852 to 30 dollars in 1858, and may be accounted for by a growing shortage of eastern white pine.

'The Civil War greatly affected the price of lumber, in common with that of other commodities, through inflation, but calculated on a gold standard basis softwood values did not increase materially until after 1865. But between 1865 and 1870 softwoods parted company with general commodity values, and with the exception of one brief period have so remained until the present time.

'The softwoods reached their new price level in 1866. From that year onward lumber prices, except as indicated, remained well above the average for all commodities.

'The general level of softwood uppers from 1866 to 1890 was between 34 dollars and 40 dollars per thousand, and that of the lower grades between 14 and 18 dollars, an increase over the pre-war levels of 10 to 15 dollars and of 4 to 8 dollars per thousand, respectively. This was the period during which Lake States white pine was entering the eastern market in increasing volume, at increased transportation costs of about 5 dollars per thousand. Undoubtedly the increasing absorption of timber from the Lake States by the Middle Western States, whose development was proceeding rapidly, and the growing scarcity of local timber also exerted a lifting influence on softwood prices. Large rafts of lumber were

passing down the Mississippi River to Memphis, Vicksburg, and even New Orleans.

TABLE XVIII. *Trend of average wholesale prices in U.S.A. (eastern markets). (From the Capper Report.)*

	Softwoods, 1-inch stock.		*Hardwoods, 1-inch stock.*	
	First quality per M. feet.[1]	*Average quality per M. feet.*[1]	*First quality per M. feet.*[1]	*Average quality per M. feet.*[1]
Year.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
1840 . . .	20·91	10·50	—	—
1845 . . .	21·46	10·50	—	—
1850 . . .	24·35	10·50	—	—
1855 . . .	26·15	11·00	11·03	—
1860 . . .	24·45	11·50	12·24	—
1865 . . .	20·43	9·25	13·57	—
1866 . . .	41·32	14·28	20·94	—
1870 . . .	37·70	14·01	24·89	—
1875 . . .	39·93	13·33	27·64	—
1880 . . .	38·41	14·00	31·62	—
1885 . . .	41·51	17·00	31·46	—
1890 . . .	34·48	16·40	33·07	—
1895 . . .	29·39	16·55	34·52	24·76
1900 . . .	34·06	21·50	39·29	27·57
1903 . . .	41·93	21·20	46·43	33·72
1905 . . .	42·59	22·06	41·97	31·80
1910 . . .	43·50	24·60	49·17	35·61
1911 . . .	45·06	24·52	50·59	35·45
1912 . . .	44·53	25·29	51·44	35·73
1913 . . .	44·92	27·88	53·99	38·61
1914 . . .	42·76	25·19	54·94	38·23
1915 . . .	41·89	24·68	52.94	35·49
1916 . . .	41·53	26·86	54·59	37·64
1917 . . .	42·60	29·09	56·00	38·92
1918 . . .	51·45	39·90	66·65	46·42
1919 . . .	61·58	44·42	72·62	55·54
1920 . . .	131·55	73·26	*178·82	*123·80

* Figures apply to first three months.

'The financial depression which began in 1873 caused a temporary decline of lumber prices in common with all commodities. Following 1879 softwood lumber prices advanced steadily until 1883, when the upward trend was checked by an increasing inflow to the large eastern markets of yellow pine from the forests of Virginia,

[1] The unit of the American softwood trade is 1,000 board feet, or M.b.f. This unit is about half a *standard* (165 cubic feet) which is the unit of the European trade.

North Carolina, South Carolina, and Georgia, and the rapidly increasing cut in the Lake States. Supplies were brought to New York, Philadelphia, Boston, Baltimore, and other eastern centres by water transportation.

'During the year 1887, for example, over 200 million feet of southern pine was received at New York, an increase of nearly 30 per cent. over 1886. Only a few years before there was but one yellow pine yard in New York, and the receipts were insignificant.

'The interregional competition which grew out of the rapid expansion of the lumber industry in the Lake States and the South during the eighties, together with the continued production in New England and Pennsylvania, was unquestionably the dominating factor in crowding softwood lumber prices downward and holding them at temporarily low but fairly uniform points for a decade following 1890. The average value of the upper quality lumber centred about 30 dollars per M. feet and that of the lower quality between 16 and 17 dollars per M. feet. During this period the lumber price trend coincided very closely with the ups and downs of the all commodity price average.

'By 1900 the Lake States white pine and the South Atlantic yellow pine were waning factors in the New York market. This was due not only to the decline in cuts in these regions but also to the increasing absorption of lumber by expanding markets west of New York. The bulk of the softwood lumber in the eastern markets came more and more from the Gulf States by rail and water, with increased transportation charges totalling 6 to 9 dollars per thousand. This resulted in prices again moving steadily upward and the establishment of a new level. . . .

'From 1903 to 1917, the period of greatest decline in the cut of the Lake States, the level of softwood prices remained fairly uniform. Upper grades averaged from 40 to 45 dollars and lower grades from 24 to 26 dollars per thousand, an advance of from 10 to 15 dollars and from 5 to 10 dollars, respectively, over the previous level. There were, of course, minor fluctuations, and since 1907 an abnormal pressure downward on prices arising from weak markets and overproduction in most, if not all, of the producing regions. This is especially true of the years 1914 to 1916, a period of great regional competition in all large softwood lumber markets.

'In 1917, it will be noted, the curve for all commodity prices advanced sharply beyond softwood lumber prices for the first time since 1865, due, of course, to war conditions and the fixing of prices by the Government for the more important softwood species.

'With the close of the war came the opening of a new period. Radical changes had taken place in the general situation. The strain of overproduction and intense regional and interregional competition was markedly relaxed. The cut of southern pine had fallen off some $3\frac{1}{2}$ billion feet since 1915, and lumber production in practically all regions excepting the West was below normal. With the first development of sharp demand following the middle of 1919, therefore, there was demonstrated as never before in the history of lumber prices the effect of regional reduction of lumber production and its consequent weakening of the great levelling influence of interregional competition.

'By March 1920 average mill prices in both the South and the West were more than double the average prices received in 1918 and more than three times those of 1914. These increases were swiftly reflected in the large eastern markets. The average value of upper softwood grades was 42 dollars per thousand in 1914, 51 dollars in 1918, and 131 dollars a thousand in March 1920. Similarly, lower grade material rose from 25 dollars in 1914 to 40 dollars in 1918 and to 73 dollars in 1920.

'These phenomenal price advances, although precipitated by a variety of factors, unquestionably reflect in part a current transition to another lumber price level, the measure of which is clouded in present abnormal conditions of trade and finance, supply and demand. The new level will be founded on permanent increases in production costs and the increasing extent to which eastern markets will have to draw upon western lumber at transportation costs of 15 to 20 dollars per thousand feet.

'Softwood wholesale lumber prices since 1840 have therefore passed through three main levels in eastern markets and are now apparently in the initial stages of the fourth. The first level, prior to 1861, was characterized by local supplies and upper grade prices of 20 to 25 dollars per M. The second extended from 1865 to about 1900, with prices of from 35 to 40 dollars, and supplies drawn from the Lake States, and the third level, from 1900 to 1918, with the Southern States as the main source of supply, and with prices of 40 to 45 dollars. Prices for the fourth level are not yet stable.'

During the years which have elapsed since this Report was published prices have followed a course which was not fully foreseen by the authors. The high profits which were obtainable in 1919 and 1920 from lumbering on the west coast led to excessive production, with the result that prices again declined heavily. The authors of the Report were probably justified, however, in their view that a new

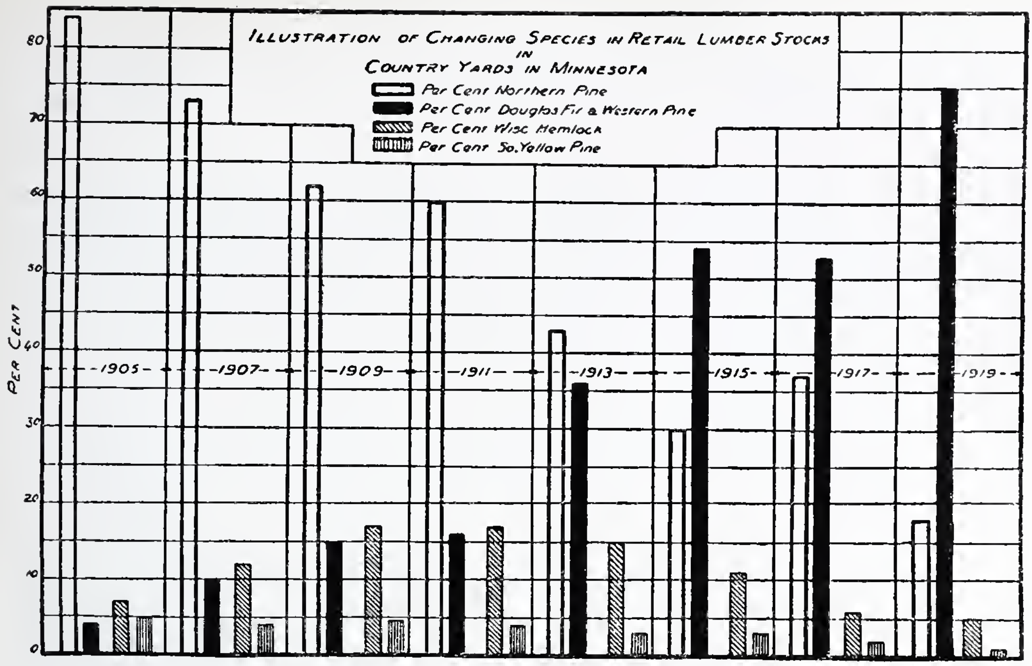

FIG. 8. Changes in kinds of wood in lumber yards in Minnesota, U.S.A., from 1905 to 1919.

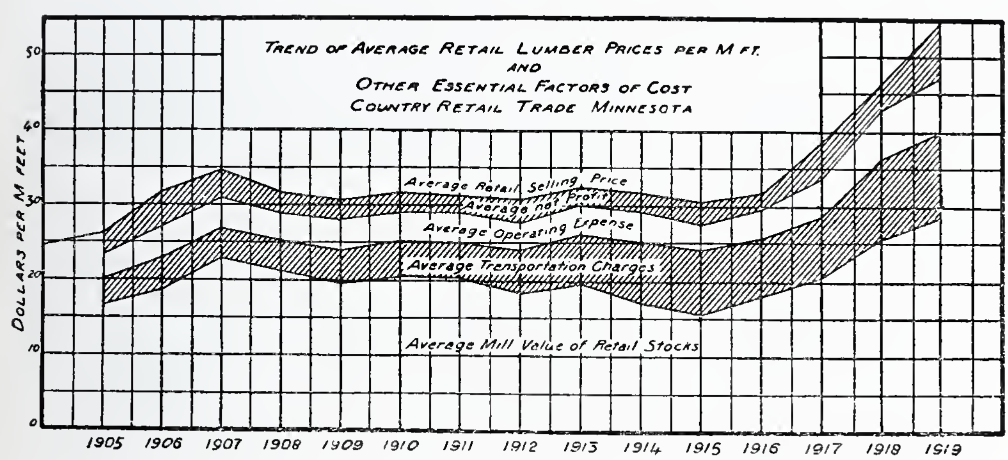

FIG. 9. Influence of various factors on selling-price of timber in Minnesota from 1905 to 1919.

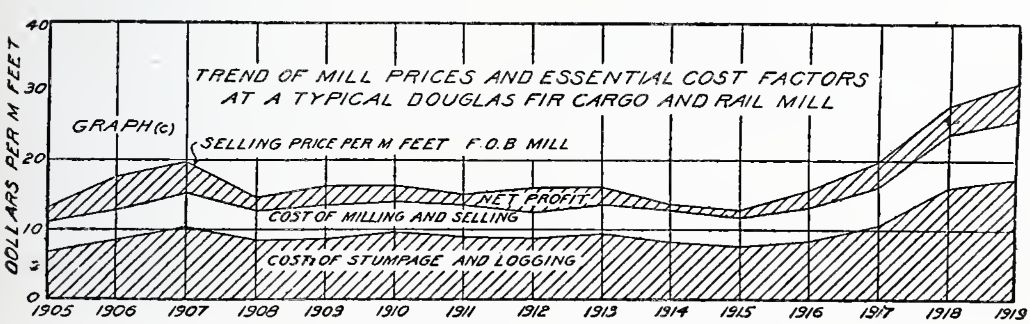

FIG. 10. Cost of production of Douglas fir timber in Western U.S.A., from 1905 to 1919.

price level for timber in the eastern markets has been reached, though this price level is likely to be considerably lower than that of 1919.

Fig. 8 also shows in a graphic manner the change over from northern white pine (Weymouth pine) to Douglas fir as the mainstay of the eastern timber supply. In 1905 over 80 per cent. of the retail lumber stocks in the country yards in Minnesota was northern white pine; in 1919, 75 per cent. was Douglas fir which came from the other side of the Rocky Mountains.

Fig. 9 shows the effect of this on the average cost of transport. Fig. 10 shows that despite the growing market importance of Douglas fir the selling price in the West did not rise until the war shortage occurred.

It may be noted that the price of 20 dollars per thousand board feet is equivalent to 1*s.* per cubic foot or £2 10*s.* per load. If figures are compared on this basis it appears that in 1875 the eastern market price for average quality softwoods was 40 per cent. lower than the British c.i.f. average prices for sawn fir; by 1895 the prices in the two regions had become equal and from 1905 till the war the American price was considerably the higher. During and after the war, when shipping freights were very high, the American price fell again below our own. The average quality of American softwoods is considerably higher than that of Baltic timber, though American sawing is less exact.

Price movements in Germany.[1] In all the German States continuous records have been kept of the prices obtained for timber in the forest, and these records are the most trustworthy for studying movements in the prices of standing timber. In Table XIX a list of prices for various timbers is given, in marks per cubic metre, for the period 1883 to 1912. These prices show a more rapid appreciation than the c.i.f. import prices in the United Kingdom. This is due partly to the fact that a rise in the real price of timber should cause a greater percentage rise in the price in the forest, as explained on p. 88, and partly to the great improvement in extraction facilities in German forests. A great amount of capital has been spent on building and improving forest roads in Germany, and this capital yields a return in the better prices which can be realized for timbers in the forest; part of the appreciation shown in the Table should be regarded as interest on money which has been spent on such permanent works.

[1] A detailed study of timber prices has been made by K. Rubner, *Die Bewegung der Holzpreise in Deutschland*, J. Newmann, Neudamm, 1920.

TABLE XIX. *Movements of prices of standing timber of various species in Germany.*

Prices in Marks per Cubic Metre.[1]

	Prussia.						*Würtemberg.*				*Price Index No. (Schwitz).*[2]
	Timber.				*Firewood.*		*Timber.*		*Firewood.*		
	Oak.	*Beech.*	*Spruce.*	*Pine.*	*Beech.*	*Pine.*	*Oak.*	*Conifers.*	*Beech.*	*Conifers.*	1900 = 100.
1883/84	19·4	12·3	11·2	9·2	4·6	3·3	25·3	12·9	6·1	4·1	96
1885/89	18·7	11·4	12·4	9·5	4·6	3·4	26·4	13·5	6·2	3·9	87
1890/94	19·6	11·4	12·9	9·8	4·8	3·5	34·4	15·0	6.9	5·0	90
1895/99	20·2	12·2	14·8	10·9	5·0	3·6	35·3	18·3	7·1	5·6	82
1900/04	20·4	12·6	14·6	12·8	5·4	4·3	36·0	18·9	8·2	6·2	95
1905/09	23·7	15·2	15·4	15·1	5·8	4·8	41·0	21·0	9·4	7·0	105
1910/12	23·9	14·7	14·9	16·0	5·3	4·4	45·1	22·3	9·2	6·6	—
Percentage rise in price from 1883/4 to 1910/12 %	22	20	33	74	15	33	78	73	51	61	
Rate of Rise per annum %	0·7	0·7	1·0	2·0	0·5	1·0	2·1	1.9	1·4	1·7	

Note.—The import duty on timber in the round was M. 0·60 till 1885, M. 1·20 from 1885 to 1906, and M. 0·72 for softwoods and M. 1·08 for hardwoods from 1906 to 1921.

1 Derived from M. Endres, *Handbuch der Forstpolitik*, 1922, p. 94, and based on Rubner's figures.

2 As quoted by Layton.

Rubner's detailed figures[1] show that the poorer grades of timber have advanced in price more rapidly than the better grades. Thus in the Roggenburger Forest in Schwabia the price for first quality spruce timber advanced from 12·3 M. per cubic metre to 24·5 M. in the period 1885/89 to 1910/14, which represents an annual appreciation of 2·81 per cent. During the same period fourth quality timber advanced from 6·8 M. to 20·0 M., which represents an annual appreciation of 4·42 per cent. Again, in the Black Forest first quality spruce and silver fir advanced from 17·3 M. to 24·6 M., an annual appreciation of 1·42 per cent., whilst fifth quality spruce and silver fir advanced from 7·9 M. to 17·3 M., an annual appreciation of 3·19 per cent. Improvement in transport facilities will account partly for this difference as it tends to produce an equal, *and not a proportional*, enhancement in the value of standing timbers of various qualities; but it cannot account for poor quality timber having risen in price by a greater amount than good quality. This must be due to a change in uses such as an increased demand for mine props or wood pulp. In Saxony the most rapid rise in prices appears to have occurred in medium sized spruce.

Since the war timber prices in Germany have been depressed owing to the importation of large quantities of cheap timber from the Succession States. This competition has affected the price of high grade more than that of low grade timber. Thus, comparing the Bavarian prices for spruce in June 1926 with the average prices for 1913,[2] first and third qualities respectively remained the same and fell 2 per cent., whereas fifth quality rose 18 per cent. and pulp wood 26 per cent. Oak prices in Prussia rose between 60 and 70 per cent., and other hardwoods to an intermediate extent. The wholesale price index for June 1926 (1913=100) was 125.

Relation of the price of standing timber to the price of sawn timber. In discussing timber prices it is necessary to distinguish very carefully between the price of standing timber and the price of timber in various stages of conversion and transport. In the foregoing notes on price movements the prices quoted for Britain and U.S.A. are based on the prices of timber in consuming markets, whereas those quoted for Germany are the prices of standing timber. Consequently these movements are not strictly comparable. If wages and cost of transport remain constant there should be a constant difference between the price of standing timber in a particular forest and the price of converted timber in a particular market. In other words, conversion and transport add an increment to the price which

[1] Loc. cit. [2] R. Ortegel, *Die Forstwirtschaft*, Berlin, 1927.

is constant and not proportional to the standing price. For this reason fluctuations in the price at the market should cause much more violent fluctuations in the price of standing timber.

No detailed examination of the components which go to make up the price of timber in the world markets has yet been made, but Table XX[1] contains an assessment, based on the costings of a number of firms, of the items which go to make up the price of timber loaded in Finnish ports.

TABLE XX. *Saw-mill costings in Finland.*

Cost of logs per cubic foot in mill-pond.

	Fmks.	
Purchase price of standing timber [2]	2·00	
Felling and hauling to floating river	1·60	
Floating Association	0·93	
Management, depreciation, interest	0·30	
Loss of timber in river, &c.	0·16	
Total	4·99	say *Fmks.* 5·00

Cost of sawing per standard (165 c.f. sawn wood).

245 c.f. logs at *Fmks.* 5	1,225	
Raising from pond and piling for winter	36	
Wages	106	
Stores	20	
Power and Light	24	
Repairs (mill and houses)	50	
Piling in Timber yard	130	
Transport and/or loading	120	
Sundries	150	
Insurance	20	
Management	40	
Depreciation	150	
	2,071	
Interest on capital—say	200	
net cost, f.o.b.	2,271	i.e. £11 15 0
Commission and *del credere* [3]	110	
gross cost, f.o.b.	2,381	i.e. £12 7 0

Note.—Fmks. 193 is approximately equal to £1. Thus Fmk. 1·00 is equivalent to $1\frac{1}{4}$*d.*

[1] Hiley, *The Forest Industry of Finland*, Oxf. For. Memoirs, No. 8, 1928.
[2] Measured by Finnish rule, which gives about 23 per cent. less than true measure.
[3] *Del credere* is a guarantee, given by the agent, that purchasers are solvent.

The average cost of freight and insurance from Finnish ports to London in 1928 was about £2 4*s.* per standard, and this added to the gross f.o.b.[1] cost of £12 7*s.* gives a c.i.f. cost of £14 11*s.* The average c.i.f. price of sawn softwood from Finland, as calculated from Table XI, was £14 3*s.* 9*d.*, and this gives an apparent loss to the shipper, though the loss is considerably less than the interest on capital allowed in Table XX.

The average cost of felling, hauling to river, and floating, is about Fmks. 3·00 per cubic foot. Allowing Fmks. 0·50 for felling, this leaves Fmks. 2·50 for hauling to river and floating. In practice the cost will vary from nothing for trees growing on the side of a river near the mill to a large sum for trees growing at a great distance from a mill and far from a river. But, with the average mill envisaged in this table, timber which cost Fmks. 4·50 to bring to mill could not profitably be cut and would therefore have a standing value of nil, i.e. the timber would be 'unmerchantable'.

A rise in price of £3 per standard in the London market should, if other things remain constant, enable a saw mill in Finland to pay Fmks. 2·50 more per cubic foot for standing timber. The effect of this should be to raise the value of timber standing near the mill from Fmks. 4·50 to 7·00: timber at an average distance from Fmks. 2·00 to 4·50: and timber which was previously worth nothing to Fmks. 2·50. This is a rise of 55 per cent. in the first, 125 per cent. in the second, and infinity per cent. in the third case. In practice, however, forests which are at present unmerchantable should have a sale value because of the prospect of their becoming merchantable in the future.

Thus the prices of standing timber may be expected to show much more violent fluctuations than the prices of sawn timber. Table XXI shows that in Finland this is the case.

During the years 1921 to 1927 the price of standing timber fluctuated from Fmks. 1·37 to 4·36, a difference of 218 per cent., while the average price for sawn goods has only fluctuated between Fmks. 2,080 and 2,570, a difference of 24 per cent.

In a Douglas fir logging operation on the north-west coast of U.S.A. conducted during the years 1910 to 1913[2] the average annual overall cost of felling and extracting by specially built railway to mill pond or tidal water varied from 2·4*d.* to 4·5*d.* per cubic foot

[1] F.o.b.=free on board, i.e. the price when loaded on ship at the port of export. C.i.f. (cost, insurance, freight) is the price on arrival at port of import.

[2] W. H. Gibbons, 'Logging in the Douglas Fir Region', *U.S. Dept. Agric. Bull.* No. 711, 1918.

of sawn timber. Intensive studies are now being made, both in America and Sweden, of the relation of the cost of felling and extracting timber to the size and position of the trees, and such studies should prove of much value.

TABLE XXI. *Relation between the price of standing timber sold from Finnish State forests and the price of sawn timber.*[1]

Year.	*Aver. price of standing timber per cub. ft.* *mks.*	*Aver. price of raw material in a standard of sawn goods.* *mks.*	*Aver. price per standard of sawn goods.* *mks.*	*Cost of logs in percentage of price of sawn goods.* %.
1921 . . .	1·37	335·65	2,150	16
1922 . . .	2·41	590·45	2,270	26
1923 . . .	2·53	619·85	2,570	24
1924 . . .	1·87	458·15	2,280	20
1925 . . .	1·77	433·65	2·110	21
1926 . . .	2·79	683·55	2,080	33
1927 . . .	4·36	1,068.20	2,280	47

(These figures are not in entire agreement with my own information, and I do not know the sources from which they were obtained.)

[1] *Bank of Finland Monthly Bulletin*, October 1927.

PART II

THE PROFITABLENESS OF FORESTRY

VI

THE RATE OF INTEREST

General: importance of rate of interest in forest finance. The meaning of interest: interest paid yearly and half-yearly. The premium concept of interest: simple and compound interest. Factors affecting the rate of interest: supply and demand. Effect of price movements on the rate of interest: example from Midland Railway Company Debentures. Shares and loans. Comparison of calculated financial yields from forestry with rates of interest earned by other investments: if the price index is rising or falling: if timber prices are rising or falling. The forest per cent.: reasons adduced for accepting a low rate of interest in forestry. The rate of interest earned on forest capital.

General. The economics of the cultivation of timber trees presents certain difficulties which, though not entirely absent from the analysis of other industrial undertakings, are intensified to a conspicuous degree in the case of forestry. The most prominent of these difficulties are due to the long duration of the period between the initiation of a forest stand and the harvesting of the crop. The construction of a motor-car may now be completed in three days, and by careful analysis of accounts the expenses incurred in raw materials, labour, supervision, wear and tear of machinery, and interest on capital employed should be capable of fairly accurate calculation. From these figures the cost of manufacture can be estimated, and it can be determined whether the selling price allows a profit to the manufacturer or not. The precision of the results must always be open to question, and it is unlikely that two independent investigators would arrive at quite the same conclusions, but there is general agreement about the methods, and results should not be very divergent.

In forestry it is otherwise, and totally different results are frequently obtained by independent computors from the same figures. Any amount which may be estimated as the cost of growing timber is open to the gravest criticism, and the estimate of one man may be double that of another who works on only slightly different premises. In nearly every case the receipts from the sale of timber will exceed by many times the actual sums paid for land, material, and labour during a rotation, and whether the forest has been managed with profit will depend to an overwhelming extent on the rate of interest which is charged to the capital involved. If a balance sheet is drawn up interest on capital may represent as much as 80 or 90 per cent.

of the total costs, and a difference of 1 per cent. in the rate of interest charged may in some cases alter the computed cost of production by as much as one hundred per cent.[1]

The difficulty of realizing in forestry rates of interest which are commensurate with those obtained in other industries has led propagandists to belittle the importance of compound interest, and the literature of forest economics is marred by many false arguments on the subject. Thus it has been suggested that timber is not formed by trees according to the law of compound interest, and that consequently theories of finance should not be imposed on forestry. Frequent attempts have been made to introduce simple in place of compound interest or, as this was generally considered too favourable to forestry, to use a mixed system of compound and simple interest.[2] In more recent times the literature has been dominated by the controversy between the schools which respectively uphold the 'forest rent theory', and the 'soil rent theory', of which the former refuses to consider the rate of interest at all.

This controversy will be analysed in a subsequent chapter. In the present the general economic theory of interest and the factors which cause it to vary will be discussed.

The meaning of interest.[3] The rate of interest on capital is the relation between the money value of the income derived from the capital and the money value of the capital itself. Thus if an investment of £200 yields an income of £8 per annum then the rate of interest is $\frac{8}{200}$ or $\frac{4}{100}$ per annum; this is generally expressed as '4 per cent. per annum'. The rate of interest need not be expressed in terms of one year; thus *The Globe*, one of the early ships belonging to the East India Company, earned a return of 218 per cent. on a cruise of five years.[4] In many cases the rate of interest is 2 per

[1] See Table XLI, p. 183, where in Quality III stands it is shown that the cost of production of oak trees of 30 c.f. (when cost of annual management is 10*s.* per acre) is 5*s.* per c.f. at 3 per cent. interest and 10*s.* 8*d.* at 4 per cent. interest. On short rotations the difference would be less.

[2] For the history of methods of simple and mixed interest see J. Lehr, *Lorey's Handbuch der Forstwirtschaft*, vol. iii, 1912, pp. 13 et seq.

[3] No attempt is made here to define 'capital', 'income', or many of the other economic terms used. Definitions proposed by different authors are very diverse, but in most cases the application of the terms to forest economics will be free from ambiguity. It should be stated, however, that the writer has generally followed the usage of Professor Irving Fisher and has drawn extensively for this chapter on two of his books, *The Nature of Capital and Income* (1919) and *The Rate of Interest* (1907). The reader is referred to these books for more precise statements of the meaning of terms.

[4] Kirkaldy, *British Shipping*, London, 1914. This return is equivalent to compound interest at a rate of 26 per cent. per annum.

cent. per half year. The latter rate is generally described as 4 per cent. per annum *payable half-yearly*, but it is not the same rate of interest as 4 per cent. per annum payable annually. For if £100 is invested for one year at 4 per cent. per annum *payable annually* the investor receives £104 at the end of the year. If, on the other hand, he invests £100 for one year at 4 per cent. per annum *payable half-yearly* he receives £2 at the end of six months and £102 at the end of the year. He might reinvest the £2 for six months at 4 per cent. per annum and receive £2·04 for it in which case his original £100 would yield £104·04 at the end of the year.

In forestry it is usual to calculate all rates of interest as so much per cent. per annum payable annually. This facilitates computation but has the disadvantage that our rates represent rather less than the same rates for investments which pay interest half-yearly as is the more general practice.

The premium concept of interest.[1] This is of particular value in the study of compound interest. This concept can be most easily explained in relation to the psychological observation that present satisfaction is more attractive than an equal amount of satisfaction in the future. It follows from this preference that if present satisfactions are to be balanced against future satisfactions the latter must be greater than the former. If a man prefers to have a year hence the satisfactions which may be bought for £104 rather than present satisfactions which would cost £100, then he will be willing to invest £100 for one year at 4 per cent. interest. To him the value of £104 a year hence is equal to or greater than the value of £100 to-day.

If the rate of interest remains constant from year to year at 4 per cent. the owner of £100 may regard his investment in two ways. At the end of each year he may draw £4 as income leaving the principal of £100 intact, or each year he may reinvest the interest. In the latter case his capital will amount at the end of the first year to £104; this sum being reinvested at 4 per cent. will grow to $104 \times \frac{104}{100}$ or £108·16 by the end of the second year, to £112·49 by the end of the third year, and to £148·02 by the end of the tenth year. The former alternative is an example of simple interest, the latter of compound interest. The difference between the two is that in the one instance the interest is withdrawn annually, in the other it is added to the principal; and this addition need not be conscious since there are many forms of investment in which it occurs automatically.

[1] For literature see Irving Fisher, loc. cit.

A familiar example of this type of investment is a National Savings Certificate for which the investor pays 16*s*. and realizes 20*s*. at the end of six years, an appreciation equivalent to compound interest at a rate of 3·8 per cent. per annum.

The North American Company reinvests all its net income in capital expansion and pays no cash in dividends on ordinary shares. In place of dividends it issues annually to each ordinary shareholder an amount of common stock. If the shareholder keeps this stock his investment is a compound interest investment; he may, however, sell the additional stock which is credited to him each year, and in this case the investment yields him simple interest.

Factors affecting the rate of interest: Supply and Demand. The rate of interest at which money is invested, or, in other words, the price of money, is determined by many interacting influences, and is subject, like the price of other commodities, to the laws of supply and demand. The commodity in this case is *the use of* capital. Now capital is a term which denotes the material objects owned by human beings (i.e. the wealth) at any one time. A very small proportion of this wealth is money, and when a company needs to raise capital what it requires is not generally money but land, buildings, machinery, &c. An investor may actually place land or a building at the disposal of a company and it is, in any case, the material objects which, under the influence of human labour and direction, yield an increase of wealth a part of which is income. But the rate of interest is the relation of the *money value* of the return to the *money value* of the capital, and the money value of the capital[1] in any undertaking must be measured before the rate of interest which it yields can be ascertained. For this reason investment generally takes the form of money passed from one person to another or if actually goods are invested, as when a private venture is converted into a public company, the value of these goods is estimated.

Capital is demanded for many purposes, and a few examples will

[1] In most forms of industry the money value of capital is either the amount of the original investment or is determined by capitalizing, at the current rate of interest, the income which it earns or may be expected to earn. Forestry, however, is a special case. The greater part of the capital in a forest is represented by the standing timber and this same timber, when felled, is converted into income; the machinery which produces the product is of the same nature as the product itself. If a plantation is increasing in value each year by £20, then its value, if determined by capitalizing the income at 5 per cent., is £400. The timber, however, might fetch £1,000 if sold to a timber merchant for felling and, as this is the sale value of the plantation, we are justified in saying that it is only earning 2 per cent. on its realizable value.

suffice to show the manner in which demand operates. A manufacturer finds that by inserting a new machine at a cost of £1,000 he can reduce his annual costs of production by £100. It is then worth while for him to borrow the £1,000 if he can do so at a rate of interest of 5 per cent. since, though he has to pay £50 a year to the lender, he saves himself £100 leaving him a net gain of £50 per annum. It might, indeed, be worth while for him to pay more than 5 per cent. but not more than 10 per cent. Again, a man pays a rent for his house of £80 a year. He finds that at a cost of £2,000 he can build a house which will provide greater comfort than his present house, and for this greater comfort he is willing to pay an additional £20 a year, making a rent of £100 per annum. If he can borrow the £2,000 at 5 per cent. or less, he is prepared to build, but he will not be prepared to pay interest at a higher rate than 5 per cent.

These examples make it clear that if money can be borrowed at a low rate of interest many more people will be anxious to borrow than if the rate of interest is high. Thus the relationship between the rate of interest and the demand for capital is similar to that between price and the demand for a commodity explained on p. 57, and a similar graph can be drawn associating the two.

The supply of fresh capital comes from the excess of earnings over consumed income. It represents the savings of the community and involves abstinence on the part of the possessors. Abstinence is not a pleasure in itself but is induced by the hope that it will give rise to greater satisfaction in the future. If the capital which is saved is lent at a high rate of interest it will produce greater material satisfaction in the future than if it is lent at a low rate of interest, and consequently when the rate of interest is high there is a greater inducement to save than when the rate of interest is low. Greater saving produces a greater amount of capital for investment, so that, *coeteris paribus*, the higher the rate of interest the greater the supply of new capital for investment. Thus the relation between the rate of interest and the supply of capital is similar to the relation between the price of a commodity and its supply as depicted in the graph on p. 58.

The idea that the prospect of future satisfactions is an inducement to saving can be readily expressed in terms of the premium concept of the rate of interest. A man who has £100 to spend to-day may, by lending it at 5 per cent. interest, realize £105 a year hence. He thus has the choice of spending £100 now or £105 in a year's time; and whether it is better to spend or to lend will largely depend on the rate of interest he can obtain.

The psychological factor, which has here been introduced as one of the influences determining the rate of interest, may appear to be unworthy of the stress that has been laid on it in view of the fact that a very large part of the new capital which becomes available for investment each year is derived from reserves of public companies, bank balances, and other moneys which would not be spent in immediate satisfactions whatever the rate of interest obtainable. This fact cannot be ignored, but the following reasoning will show that the personal factor is still of immense importance. It has already been seen that the demand for capital depends on the rate of interest at which money can be borrowed. If other things are equal more will be borrowed when the rate of interest is 5 per cent. than when it is 6 per cent. Now let us suppose that the new reserves of public companies, &c., are sufficient to supply all the capital for which a demand exists at 6 per cent. interest, but no more. Then, if no other new capital were available the rate of interest would be 6 per cent. In practice there will be an additional amount of capital for investment from private sources, and this additional supply will lower the rate of interest until a figure is reached below which no more fresh capital is forthcoming. Thus the actual rate which is in force at any time must, to a very large extent, be determined by the views of the private investors who provide this margin of new capital.

Effect of price movements on the rate of interest. We have seen that a man may be induced to invest £100 rather than spend it on immediate satisfactions because he hopes thereby to have £105 to spend (or reinvest) next year. If during this year the average prices of commodities rose by 5 per cent., then £105 at the end of the year would buy no more than £100 at the beginning. The benefits from his abstinence would thus be nullified. If, on the other hand, prices fell by 5 per cent., during the year, then £95 at the end of the year would buy as much as £100 at the beginning and the £105 would be worth as much as £110·5 a year before. In each case the *nominal* rate of interest is 5 per cent., but the *virtual*[1] rate is *nil* in the first instance and 10·5 per cent. in the second. Thus the virtual rate of interest which is received is very greatly affected by any changes in the purchasing power of money. If the psychological factor is now introduced it will be clear that when prices are rising a higher rate of interest should be necessary to induce abstinence and saving than when prices are falling; and there is a considerable amount of statistical evidence to show that this is the case. As the

[1] i.e. rate of interest corrected against price movements. Irving Fisher, *Purchasing Power of Money*.

subject has very important bearings on forest economics this evidence will be briefly reviewed.

During the period 1875 to 1895 wholesale prices fell by 22·4 per cent., which is equivalent to an annual fall of 1·2 per cent.; from 1895 to 1905 prices rose by 7·1 per cent., which is equivalent to an annual rise of 0·7 per cent. Thus during the first period the virtual rate of interest received on any investment was 1·2 per cent. higher

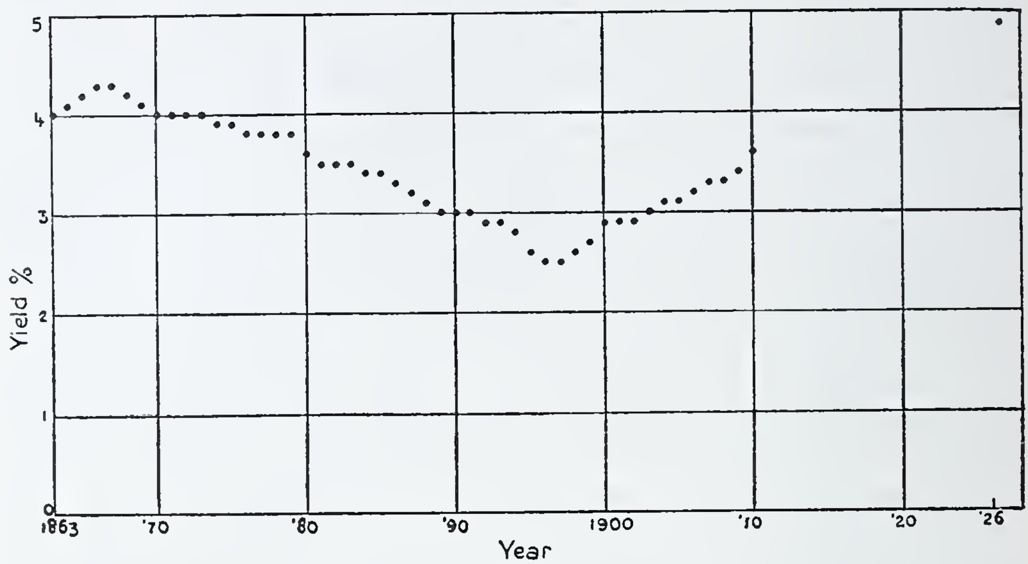

FIG. 11. Changes in the yield from Midland Railway Company Debenture Stock from 1863–1910 and the yield in 1926.

and, during the second period 0·7 per cent. lower, than the nominal rate. A fair test of the rates of interest which were obtainable during these years is the yield from the Debenture Stock of some large railway company, and Fig. 11 shows the yields from Midland Railway Co. Debenture Stock[1] for the years 1865 to 1910 and the yield in 1926. This diagram shows that the rate of interest was lowest in 1896, the critical year in which prices ceased to fall and began to rise. Further, during the period of falling prices rates of interest fell till in 1896 the nominal rate was 2·5 per cent., which was equivalent to a virtual rate of 3·7 per cent. on the experience of the price movements of the previous 20 years. In 1905 the nominal rate was 3·1 per cent., but this was equivalent to a virtual rate of only 2·4 per cent. on the experience of price movements during the preceding ten years. These results are in keeping with the following quotation from Irving Fisher:

'When prices are rising at the rate of 3 per cent. a year, and the

[1] From Macdonald, *Journ. Statistical Soc.*, March 1912, p. 378.

normal rate of interest—i.e. the rate which would exist were prices stationary—is 5 per cent., the actual rate, though it ought (in order to make up for the rising prices) to be 8·15 per cent., will not ordinarily reach that figure; but it may reach, say, 6 per cent., and later, 7 per cent. This inadequacy and tardiness of adjustment are fortified, moreover, by law and custom, which arbitrarily tend to keep down the rate of interest.'[1]

Fluctuations in the purchasing power of money not only affect the rate of interest at which it is worth while for people to invest; they also affect the demand for capital. Rising prices tend to increase the profits from business enterprise in two respects. If there is a prospect that prices will be lower six months hence than they are now intending purchasers will put off buying till the last possible moment; this will often result in their not buying at all. But when prices are rising sales are much brisker and retailers will profit by carrying as large a stock as possible. Again, the manufacture of an article takes time and the profits of a manufacturer are affected by any difference which exists between the level of prices when he is producing and the level at which he sells. He is producing at a certain cost to-day; when manufacture is completed six months hence he will sell at a better price if prices have risen in the meantime than if prices have fallen. The actual difference in price may be a very small percentage of the total price, but may, nevertheless, have an important influence on the margin of profit. Thus rising prices are good both for producers and middlemen, and the encouragement which they give to business enterprise increases the demand for capital and makes it possible to pay the higher rates which investors demand.

Shares and loans. Most investments take one of two forms which may be called *shares* and *loans*. By buying a share, e.g. an ordinary share in a company, the purchaser becomes part owner of a property. Thus if a company issues £100,000 in ordinary shares, the owner of £1,000 worth of this stock owns a one-hundredth part of the properties of the company. No rate of interest is guaranteed to him but, if the company is successful, he will receive *dividends* which represent a rate of interest on his investment. The company, may, however, borrow further capital in another form, as debentures or preference shares. On these a fixed rate of interest is payable and, though the investor who lends money in this form cannot expect to obtain higher rates of interest than that agreed upon, he has greater security than the holder of ordinary shares in that his interest is a first charge on the income of, and his principal, in the case of

[1] Irving Fisher, *Purchasing Power of Money*, 1920, pp. 57–8.

debentures, is secured against the real property of, the company. These debentures and preference shares, like all government stock and mortgages, are loans and are affected in a different manner from ordinary shares by financial events. There are intermediate forms of investment, such as participating preference shares.

The real difference between loans and shares is that the former bear a fixed rate of interest and the latter a variable rate. If the purchasing power of money falls so that prices rise the holder of a loan receives the same income as before but is actually poorer; a rise in prices, however, may be beneficial to industry, and companies may even earn bigger profits than before, so that a shareholder may receive larger dividends and may consequently be as well, or better, off. In general, rising prices are favourable to shareholders, but unfavourable to loan-holders. Conversely, falling prices are, in general, favourable to loan-holders, but unfavourable to shareholders.

An extreme case of this occurred during the inflation period in Germany and France after the war. In Germany the holders of Government stock received a fixed income in marks which came to be worth practically nothing; at the same time many of the industries were highly prosperous. During this period ordinary shares were a much safer investment than debentures or government stock. The reverse, however, is generally held to be true, and undoubtedly was true during the period of falling prices towards the end of the last century.

In a financial sense forest property behaves like shares and not loans. If prices rise the yield from forestry rises and if prices fall the yield from forestry falls. It has frequently been pointed out in Germany that, whereas those who had their capital in Government stock lost the whole, those who owned forests received a continuous and satisfactory profit. This was due to the phenomenal rise in prices. If, however, prices had fallen instead of rising the holder of government stock would have profited and the owner of forests would have lost money, or, at any rate, would not have received a higher real income. These facts should be borne in mind when a comparison is drawn between the attractiveness of investments in forestry and government stocks or other loans.

Comparison of calculated financial yields from forestry with rates of interest earned by other investments. Any one who invests money in forestry does so with the prospect of future returns. These returns may be expressed as a rate of interest on his investment and, as is explained elsewhere, this rate of interest is called the

'financial yield'.[1] If this financial yield is to be estimated the sums to be spent in acquiring land, planting, and tending must be set against the expected yields from the sale of timber, thinnings, and other produce. It is generally assumed, for a first approximation, that both costs and prices will remain at their present level, and most forest calculations are made on this assumption. But any alterations in timber prices between the time of investment and the time of realizing profit will change the rate of interest that the forest owner receives, and it is the object of the present section to show how such changes may be evaluated.

Timber prices may vary in three ways:

(1) The average prices of commodities may rise or fall and timber prices with them.

(2) The average prices of commodities may remain constant, but timber prices may rise or fall.

(3) The average prices of commodities may rise or fall and timber prices rise or fall, but not proportionately to other prices.

(1) In this case the change in timber prices is due entirely to a change in the purchasing power of money. If this falls both costs of management and timber prices will rise; if it rises, both these will fall. It may be shown that if prices rise constantly at a rate of x per cent. per annum and if p is the financial yield, as calculated with fixed prices, and p_1 the actual rate received with rising prices, then

$$p_1 = p + x + \frac{px}{100}.$$

Thus, if, on the assumption of fixed prices, a financial yield is calculated at 4 per cent. the corresponding financial yield, if prices rise $1\frac{1}{2}$ per cent. per annum, will be 5·56 per cent. Similarly, if prices fell $1\frac{1}{2}$ per cent. per annum, the corresponding financial yield would be 2·44 per cent. Now, a nominal rate of interest of 5·56 per cent. is equivalent, if prices are rising $1\frac{1}{2}$ per cent. per annum, to a virtual rate of 4 per cent. From this it will be seen that progressive changes in the purchasing power of money affect the nominal, but not the virtual, rate of interest received from forestry. Thus financial yields from forestry estimated on fixed prices should be compared, not with the nominal rates of interest obtainable from other investments but with virtual rates.

The conclusions set forth in the last paragraph demonstrate one

[1] See p. 134.

of the advantages of a forest investment, viz. that it yields a return which is more or less independent of the secular changes in the purchasing power of money. It is fully realized that the holder of any annuity or loan which yields a fixed rate of interest profits from a fall in prices but loses by a rise in prices. In this respect forestry is a less speculative investment than government securities or other gilt-edged stock.

(2) If prices in general remain constant and timber prices rise a forest owner is in every way better off; if timber prices fall he is every way worse off. In order to estimate the extent to which changes in timber prices affect financial yields specific calculations have to be made for each case. The results of such specific calculations quoted in Table XXII will afford some conception of the manner in which financial yields are affected by changes in timber prices.

TABLE XXII. *Effect of a continuous change in timber prices on financial yields.*[1]

	Scots pine.			*European larch.*
	Qual. I.	*Qual. II.*	*Qual. III.*	*Qual. II.*
	%	%	%	%
Prices constant	2·4	1·8	1·2	4·9
Prices rising 1% per annum	3·7	3·2	2·5	6·2
Prices rising 1½% per annum	4·4	3·8	3·2	6·8

From the instances scheduled in this table it appears that a rise in timber prices of 1 per cent. per annum will raise the financial yield by about 1·3 per cent. and a rise of timber prices of 1½ per cent. per annum will raise the financial yield by almost 2 per cent. As there is a prospect of a considerable rise in timber prices in the future, calculations of returns based on fixed timber prices do not give an adequate picture of the rates of interest that may actually be realized.

(3) If, finally, the purchasing power of money is changing and the price of timber is changing but at a different rate from the average prices of commodities, then, in order to compare the return from forestry with that from other investments, it is necessary to calculate the movements of corrected prices of timber, to work out financial yields, assuming this change in corrected prices to continue, and to

[1] The financial yields for Scots pine are taken from Hiley, 'The financial return from the cultivation of Scots and Corsican pines', *Oxf. Forestry Memoir*, No. 6, 1926; those for larch from unpublished results.

compare this with the *virtual* rate of interest received from other investments. This is a combination of the two foregoing methods.

It is impossible to anticipate future changes in prices with any certainty, but fortunately for the forest economist the changes in corrected prices are much more regular than the changes in actual money prices. Thus it has been shown that the general trend of c.i.f. prices for 'sawn and split wood' at British ports has shown a rise in the corrected prices of about 0·8 per cent. per annum. Since 1900 the rise has been much slower than formerly, but conditions suggest that the rise will be continued within the next few decades.

The forest per cent. If a forest is sold the price which is obtained for it should represent the discounted value of all future net returns that are anticipated from the forest. Thus, in order to arrive at an approximation to the price that may be put on a forest some rate of discount has to be agreed upon. The rate of interest which is used for this purpose in forest valuations is called the *forest per cent.* The higher the forest per cent. the lower the present discounted value of future yields and, consequently, the lower the estimated value of the forest. There is, consequently, an inducement for foresters to put the forest per cent. at as low a figure as possible so as to increase the book values of the forests under their charge.

In the history of forest economics the forest per cent. has played an important part, not so much as a basis for valuing growing woods as a medium for estimating financial rotations. So long as financial rotations were calculated from soil expectation values it was necessary to work with some agreed rate of interest and the lower the rate of interest the longer is the calculated financial rotation. As most foresters are anxious to introduce into their working plans longer rotations than are justified on purely financial grounds this provides a further inducement for them to use as low a forest per cent. as can be theoretically tolerated.

Further, if calculated at a high rate of interest, the expectation value of the soil (i.e. the discounted value of all future income less the discounted value of all future expenditure, starting from bare land) is often negative, and it has been assumed, quite unwarrantably, that a negative expectation value is inherently ridiculous. The same conception is frequently expressed in another way. It is said that forestry does not, in general, yield high rates of interest, and, consequently, the forest per cent. should be low. There is here a confusion between the financial yield of a forest and the rate of discount which should be used in valuing land and forests, and

though the financial yield may be low it does not necessarily follow that a purchaser of an immature plantation will be prepared to discount its prospective value at a low rate of interest.

The following reasons have been adduced for the adoption of a low forest per cent.:[1]

(1) The price of timber is progressively rising. If prices are rising 1 per cent. per annum the rate of interest actually realized from forest investments will be about 1 per cent. higher than that estimated on present prices. Thus in calculations based on present prices a low rate of interest may be adopted.

As shown in Table XXII if timber prices are rising faster than other prices the difference in yield may be more than the difference in price increment.

(2) The security of forest investment. The chief hazard in forest investment is fire. With good management this can be kept reasonably under control, and extensive loss from insects, fungi, snow, wind, &c., can be prevented on large areas by admixture of species and efficient silvicultural management.

(3) The liquidity of the capital. The owner of mature forests can realize a large part of his capital at any time by the sale of timber. This is exemplified in Britain by the frequent felling of timber to meet death duties on estates.

On the other hand, young plantations are difficult to sell. There is no doubt that forest capital is much less liquid than gilt-edged securities.

(4) The amenities and prestige of forest ownership. In many European countries the amenities attached to landownership definitely enhance the price of land, so that investment in land generally bears a low rate of interest.

It does not follow that landowners are prepared to invest further capital at a low rate of interest in planting or forest improvement. Nevertheless, the pleasure of forest ownership and management is such that many will prefer to invest their money in this rather than commercial undertakings. Forest owning companies are influenced very little by enticements of amenity.

(5) The length of the production period. The transfer of capital and even the receipt of interest is generally attended by charges, duties, taxation, and other losses. Thus a long term investment is generally capitalized at a lower rate of interest than a short term investment. Forestry is a very long term investment, and it is

[1] M. Endres, *Lehrbuch der Waldwertrechnung und Forststatik*, 3rd ed., 1919, p. 19.

claimed that forest owners will consequently be content with a low rate of interest.

This claim is not justified by experience. If a forest worked on a system of sustained annual yield, is bought as a going concern, it can be purchased, and sold again if desired, as a revenue-yielding investment; it is, in this respect, not dissimilar from other businesses. A new plantation, on the other hand, is a long-term, compound interest investment, and it is the experience of stock-brokers that a 'lock-up' of this nature must yield a far higher rate of interest than gilt-edged stock if it is to attract investors. It is only under the abnormal conditions ruling in parts of South Africa, Australia, and New Zealand, where returns of the order of 10 per cent. compound interest are anticipated, that private companies can be floated with the object of planting bare land.

(6) The fall in the rate of interest which accompanies social and industrial development. Backward countries often offer only limited security to investors, and the rate of interest ruling in undeveloped parts of the globe is considerably higher than in more civilized countries. As civilization has advanced the rate of interest has tended to fall, and during the latter part of the last century it was sometimes regarded as a law that the national rate of interest should be a progressively decreasing quantity.

Since 1896, however, the tendency has been the other way; the rate of interest has been rising. If it were true that the rate was constantly falling this would be a strong reason for accepting a low rate of interest on a long term investment, but the experience of the last thirty years must make us extremely cautious in using this argument.

In forest practice calculated expectation values are now seldom used either for land or immature stands, and consequently the necessity for fixing a predetermined forest per cent. has largely disappeared. At the present time its chief use is in estimating the cost of production of various kinds of timber under various conditions, and for this purpose the forest per cent. should be the rate at which money can be borrowed for forest purposes. As governments can borrow more cheaply than private persons or companies, the rate which may be applied in state forestry is lower than that applicable to private enterprise. Thus the British Forestry Commission borrows from the Treasury at the Local Loans Rate which is at present about 4½ per cent., but private individuals cannot borrow at less than 5 per cent. It is generally agreed in America that forest-owning companies must charge at least 6 per cent. on invested

capital in order to obtain a satisfactory return. It should be noted, however, that in Britain the income from forestry is very nearly free from income-tax and super-tax and, for this reason, private landowners in Britain may regard a return of 4 per cent. as being attractive.

The rate of interest earned on forest capital. The actual rates of interest which may be earned in forestry are the subject of numerous calculations in this book. The rates depend on the costs of formation and maintenance of forests, the rate of growth of the trees, and the prices which are eventually obtained for timber. Further, in the various methods of estimating the profitableness of forestry interest on capital is introduced in various ways. Consequently costs and returns must be discussed before specific rates of interest can be computed, and these subjects will be dealt with in the following chapters.

VII

THE COST OF FOREST OPERATIONS

The importance of costings. The method of costings. The classification of forest expenditure. The cost of land (S). Cost of planting (C): cost of establishment; fencing against rabbits; plants; planting; influence of spacing distance: Forestry Commission costs. Examples of the cost of planting outside Britain: South Africa; New Zealand; India; Finland. Direct seeding. Natural regeneration. The cost of annual maintenance (e).

The importance of costings. In order to obtain satisfactory financial results in forest management it is necessary to carry out the various operations as economically as possible. Cheap methods may be false economy, but expensive methods are frequently no more successful than cheap methods, and the object of the forest manager must be to obtain the best return for the money which he spends.

The factors which make for cheapness in getting work done in forestry are the same as in any other enterprise: administrative ability, power of controlling labour, and the application of sound business methods. But a forest manager endowed with these faculties may still waste money through ignorance of the costs of individual operations and consequent inability, either to choose between different methods or to trace leakages when they occur. It is, therefore, a necessary part of forest management to carry out some system of costings which will show the cost of various operations. Accurate assessment of costs is also necessary for the purpose of those financial calculations on which the major decisions of forest management should be based.

The method of costings. The method of costings is now employed throughout all modern business administration. It is becoming the practice, even on the land, with more up-to-date farmers, and, in this respect, foresters are far behind managers in other industries. The object of costings is so to classify expenditure that the costs of individual processes, operations, or areas can be distinguished. It is necessary to decide beforehand on the kind of classification which is to be adopted, as the information which can ultimately be obtained from the system will depend on the method used, and a bad classification may give no useful information. It is therefore necessary to have clearly defined objectives when a costing system is initiated and to frame a system which will give those results which are desired.

The number of items of information that a critical forester would

like to have is generally so large that a system devised to obtain all of them would be too cumbrous to handle. That this is so will be clear from the following rough list of costs which it may be desired to know for forestry under British conditions.

I. *Nursery work.*
The cost of raising seedlings and transplants of all species—per 1,000.

II. *Preparation of ground for planting.*
(*a*) Clearing scrub—classified according to nature of scrub.
(*b*) Draining—according to soil type.

III. *Cost of planting.*
(*a*) Fencing against rabbits, deer, &c.—per yard.
(*b*) Planting (i) seedlings, (ii) transplants of various sizes—by various methods.

IV. *After care.*
(*a*) Cleaning young plantations—per acre.
(*b*) Average losses for each species and planting method and cost of beating up—per 1,000 plants.

V. *Thinnings.*
(*a*) Cutting and cleaning thinnings of various sizes.
(*b*) Moving thinnings to ride—by number and distance.

VI. *Felling.*
(*a*) Felling and cleaning trees of various dimensions.
(*b*) Extraction under various conditions.

VII. *Road making and repair.*

VIII. *General management*: hedging, ditching, &c.

IX. *Supervision*, office management, &c.

Many of the items in this list are themselves complex. This is particularly true of the costings of nursery work, and the Forestry Commission method,[1] which is as simple as it can be made, will indicate the manner in which such costings may be obtained.

The Forestry Commission divides nursery work into nine categories or 'standard heads', such as: preparation of beds and sowing seed: weeding beds: preparation of lines and lining out: weeding lines, &c. To calculate the cost of production of seedlings or transplants of any age for any species it is necessary to know (1) the rate of cost for each operation, and (2) the number or proportion of

[1] R. L. Robinson, 'Methods of Plantation and Nursery Costing,' *Forestry*, ii, No. 1, 1928, p. 73.

plants that survive cultivation in each year. Thus, if 20 lb. of Scots pine seed was sown on 600 sq. yds. of ground and produced 300,000 1-year seedlings, the total cost of the seedlings is made up of:

	£	s.	d.
Cost of seed, 20 lb. at say 10s. per lb.	10	0	0
600 sq. yds. prepared and sown at £0.662 per 100 sq. yds.	3	19	5
600 sq. yds. weeded at £1·728 per 100 sq. yds. . .	10	7	4
Total	24	6	9

and the cost per 1,000 is £24 6s. 9d. divided by 300, which is 1s. 7d. per 1,000; the rates of £0·662 and £1·728 per 100 sq. yds were obtained from costings of 'standard heads'.

If in the same or subsequent year 100,000 Scots pine 1-year seedlings, occupying 200 sq. yds. become 75,000 2-year seedlings, i.e. suffer a loss in numbers of 25 per cent., the total cost of producing this change is

200 sq. yds. weeded at £1·728 per 100 sq. yds. = £3·456,
and the cost per 1,000 is £3·456 ÷ 75 = 11d.

The *rate of cost* per 1,000 of 2-year Scots pine seedlings is therefore the cost of producing $\frac{1000 \times 100}{75}$ 1-year seedlings, plus the cost of changing that number of seedlings into 1,000 2-year seedlings, i.e. $1s.\ 7d. \times \frac{100}{75} + 11d. = 2s.\ 1d. + 11d. = 3s.$ The rate of cost of transplants is obtained in the same way.

The necessary overhead costs of interest on nursery formation, general care, and supervision must be added as a proportion of the other costs.

The bases for all costings of this nature must be the time sheets of the workers and the cash account for materials. The cost of planting an area may be roughly computed from the time devoted to that particular operation, but, if isolated operations of this sort are selected for special record, there is always a danger that certain periods of work will be overlooked and not debited to any account. In order to avoid this it is necessary to refer all items of expenditure, whether for labour or material, to some category or standard head. If the total amount spent in the year under each standard head and the area covered by the work are known, the average cost per acre of each category of work distinguished as a standard head can be computed. This is the manner in which the Forestry Commission's estimate of the cost of planting per acre is made. As the number of

plants put out is also known the average cost of planting 1,000 trees can be assessed, but, unless the number of standard heads is made unduly large, this method does not disclose the comparative costs of planting 2-year seedlings and 2-year–1-year transplants, the comparative costs of notching and pitting, or other alternatives.

Such detailed comparative costings are best applied on individual estates the woodlands on which are divided into compartments. By a system of 'double entry' an account can then be opened for each compartment and items of expenditure belonging to their respective standard heads can be debited to the appropriate compartments. If the forester in charge keeps notes of the area in each compartment covered by each operation and other particulars relating to it, he can subsequently work out the cost per acre for the particular method there adopted.

Owing to variations in soil, rainfall, weed growth, and other environmental factors the cost of like operations is bound to vary from place to place and year to year, and no forester can foretell exactly what the cost of any future operation will be; but if he adopts a system of costings such as is suggested above he will be in a far better position to assess future costs than if no systematic records are kept. At present, very few British estates can provide estimates from their own experience of the differences in cost between well-known alternatives such as pitting and notching trees, or of the cost of thinning plantations at various stages in their development.

In this book knowledge of the costs of operations is required chiefly for the purpose of comparative calculations on the profitableness of various silvicultural methods. These calculations involve the use of certain formulae in which the costs have to be inserted in place of symbols. In these formulae the cost of annual maintenance generally appears as a separate item, and for this reason it is not necessary to calculate any appropriate addition to operation costs for overhead charges. It is easier to group them together in the cost of maintenance.

The classification of forest expenditure. The method of classification will depend on the purposes for which the classification is required. Since, in this book, the principal use of cost figures will be for insertion in formulae, the most useful classification will be determined by the formulae themselves. In these formulae it is usual to recognize only three kinds of costs though very detailed work would require a further subdivision. These three groups are (1) land, (2) planting, or other method of initiation, (3) annual maintenance.

The cost of land (S). The cost of the land covers the initial cost of buying the land (purchase + costs of transfer) together with works which may be required to put it into a condition fit for planting. There is frequently a doubt as to whether certain items should be included in the cost of the land or the cost of planting, and this is best decided on the following principle.

If land is bought and planted at once both the cost of the land and the cost of planting are borne in the first year, and interest must be charged on them throughout the rotation. In the next rotation planting costs are incurred again, but the cost of the land does not recur. Thus the fundamental distinction between the two items as they arise in formulae is that the land cost occurs once and only once while cost of planting is incurred at the beginning of each rotation. The best practice, therefore, is to include in S all items of expenditure which are not expected to recur in the next rotation and in C (cost of planting) all items which will recur.

On this principle the cost of clearing scrub should be included in S, as it will not be required for a second rotation. Whether the cost of drainage should be included depends on its nature and permanence. When a swamp is planted for the first time drainage is necessary, but if a satisfactory plantation is established the trees themselves may dry the land so much that further drainage is unnecessary. In such cases the cost becomes a part of S. The cleaning of drains, however, which may have to be repeated each time the land is planted should be debited to C. Fencing is nearly always temporary, so should be included in C.

This practice fits in well with 'common sense' ideas. Thus land covered with scrub is not worth so much for planting as equally good land which is bare, and the difference in value is the cost of clearing. If any saleable timber or brushwood is found among the scrub, this will help to pay for clearing and will reduce the ultimate cost of the land. At the same time land covered by scrub is generally better for tree growth than neighbouring bare land, so it may be worth while to pay a higher total price for it.

If land which is bought for afforestation is not immediately stocked interest must be charged on the cost of those parts which remain unplanted for more than a year and an allowance must be made for rates and taxes; but if such land can be let for grazing or some other purpose in the meantime, the rent may defray this interest. If devastated woodland is bought for planting the growth of such crop as remains may also contribute towards interest on the cost of the land.

The following instance will exemplify these conceptions. If 1,000 acres are bought for £2,000 (including cost of transfer) and 300 acres need clearing at a cost of £4 per acre (£1,200) and 100 acres need draining at £3 per acre (£300) the total cost is £3,500. If this area is planted up in 10 years interest may be charged on the original price of the whole for 5 years and, if such land is let for shooting and this rent pays for rates and taxes, these additional charges will amount to about £500, bringing the total up to £4,000, or £4 per acre on the average.

On any such area some of the land will be better for planting than the rest, and the purchaser may value some parts at £6 per acre and others at £2. In such cases it is less wasteful to plant the best areas first if this can be fitted into the scheme of management.

Landowners and governments frequently plant land which is already in their possession. In such cases the value of S should be the market price of the land without any allowance for cost of transfer, but with additions for cleaning and draining.

The Forestry Commission acquires land for planting either by purchase or by long lease. Many purchases include a proportion of land which is unsuitable for planting, and Table XXIII shows the prices paid for land and the prices computed on a basis of the plantable area only.

Table XXIII. *Prices paid by the Forestry Commission for land.*

	Land bought		*Land leased*	
	Average price per acre		*Rent paid per acre*	
Year.	*for all land.* £ *s.* *d.*	*charged to plantable land only.* £ *s.* *d.*	*for all land.* *s.* *d.*	*charged to plantable land only.* *s.* *d.*
1920/21 . .	1 8 0	2 17 0	2 0	3 0
1921/22 . .	1 10 0	3 0 0	2 0	2 10
1922/23 . .	2 17 6	2 17 6	1 4	2 1
1923/24 . .	2 3 5	3 13 6	1 4	2 4
1924/25 . .	1 16 3	3 9 9	1 4	2 2
1925/26 . .	1 17 0	3 18 0	2 3	3 0
1926/27 . .	3 10 0	4 0 0	2 7	2 10

Note.—These prices include buildings and timber standing on the land.

These amounts do not include the cost of cleaning land and draining, and from Table XXVI (p. 114) it will be seen that these operations cost, on the average, about £1 and 10*s.* per acre respectively. It appears therefore that the average value of S for land bought by the Forestry Commission is between £5 and £6.

There is a great deal of variety in the quality of land, and good planting land is worth much more to foresters than bad.[1] It does not, however, follow that the price of land is proportional to its value for forestry. Until the advent of the Forestry Commission there was practically no demand in Britain for land for afforestation, and, consequently, land sold according to its value for agriculture, building, or other object, but with little appreciation of its forest value. In general, land which has poor agricultural quality is of low quality for forestry also; but this is not always the case, and some deep sandy soils which are too porous for shallow rooted agricultural crops prove admirably adapted to tree growth. It is on such soils, which grow trees well but are cheap to buy, that forestry is most profitable. Land near towns is always more expensive than land of the same quality in more remote areas, but it is also more valuable for forestry, especially when those crops can be grown which yield useful early thinnings. As for agriculture, so for forestry, it is important when possible to get good land, and it may be more profitable to plant good land costing £20 per acre than bad land costing nothing.[2]

The German Forest Service generally have to pay more for land than the British Forestry Commission, and a price of £10 per acre is not unusual in South Germany.

The cost of planting (*C*). The cost of planting includes the cost of fencing (where necessary), plants and planting. The cost of clearing ground for planting should for reasons stated above be included in the cost of the land. The *cost of establishment* includes, in addition to the cost of planting, the cost of clearing weeds and 'beating up' (replacing casualties) until the plantation can fend for itself.

Under average English conditions *fencing against rabbits* forms a large part of the cost of planting. The cost per acre depends on the size and shape of the area planted, so it is usual to calculate the cost in terms of yards of fencing. At present the cost per 100 yards is approximately as follows:

2 50-yard rolls of wire netting 4ft.× 1¼in. mesh, 18 gauge, at 25*s*. per roll	2	10	0
¼ cwt. barbed wire at 20*s*. per cwt.	0	5	0
1 straining post (1/6) and 2 stays (9*d*. each)	0	3	0
30 stakes at 4*d*.	0	10	0
Labour (2*d*. per yard)	0	16	8
Total	£4	4	8

The wire netting can generally be used twice and is sometimes used

[1] Cf. p. 203. [2] See p. 204.

three times. An allowance may be made for this which will reduce the total by about £1. But if irregularly shaped areas have to be enclosed many more straining posts have to be used, and these as well as the labour involved in fixing them considerably increase the cost. On private estates 1*s.* per yard is a reasonable cost for rabbit fencing, but on some of the Forestry Commission operations, where large areas with long straight sides are enclosed, the cost may be as low as 8*d.* per yard.

The cost of labour depends very much on the nature of the ground and the method of fixing. If the bottom of the wire is sunk into the soil a trench has to be cut, and it is consequently much cheaper to peg the bottom of the wire on the soil surface where it soon becomes fixed by weeds. Costs will also vary to a great extent according to the distance that materials have to be carried. Posts and stakes may be cut from neighbouring woods and cost very little, or may have to be bought and carted long distances.

The influence of size of area on the cost of fencing per acre is shown in Table XXIV, in which the areas are presumed to be exact squares, and the cost is taken at 1*s.* per yard. The square is the most

TABLE XXIV. *Cost per acre of fencing square areas.*

Size of area.	*Length of periphery.*	*Total cost.*	*Cost per acre.*		
Acres.	*Yards.*	*£*	*£*	*s.*	*d.*
1	280	14	14	0	0
4	560	28	7	0	0
16	1,120	56	3	10	0
64	2,240	112	1	15	0
256	4,480	224	0	17	6

economical shape for planting [1] and long or irregularly shaped areas are most expensive. It is clearly advisable to wire as large an area as possible at a time, but it is difficult to get the rabbits out of a large area and to keep them out.

The cost of *plants* depends on the size, species, and manner of raising. Transplants are more expensive than seedlings, not so much owing to the cost of lining out (about 3*s.* 6*d.* per 1,000) as to the losses that occur in lined out beds. Table XXV gives representative prices of seedlings and transplants of the commoner species when bought in large quantities, but as prices vary from year to year and nursery to nursery, the list should not be regarded as a standard. A saving on these prices should be achieved in a well

[1] A circle has less perimeter for its area, but circles cannot be joined on to each other.

managed nursery, and on many estates the owners prefer to buy 1-year or 2-year seedlings and line them out in their own nurseries. This method secures the silvicultural advantage that transplants can be lifted as required so that little drying of the roots occurs.

TABLE XXV. *Representative list of prices of seedlings and transplants (prices per 1,000).*

Species.	*1-yr. seedlings.*		*2-yr. seedlings.*		*2-yr. 1-yr. transplants.*	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*
Scots pine	3	6	10	0	25	0
Corsican pine	7	6	12	6	45	0
European larch	6	0	17	6	35	0
Douglas fir	8	0	12	6	45	0
Norway spruce	2	6	7	0	27	6

The cost of *planting* varies with the size of the plants, the method of planting, the nature of the ground, and the efficiency of the organization. The cheapest planting in Britain is possible with 2-year seedlings of Scots pine on light land; furrows can be ploughed at 4½ ft. apart for 5*s.* 6*d.* per acre, and seedlings can be notched in these furrows for 3*s.* 4*d.* per 1,000, labourers planting as many as 2,000 seedlings a day, or more. At this rate plants and planting may together cost less than 50*s.* per acre. Such a rapid rate of planting is only possible where very large operations are being undertaken and the workers become exceptionally efficient. And it is only achieved when the workers are paid on a piece rate, a system which makes very thorough supervision necessary.

Notching transplants is about 50 per cent. more expensive than notching seedlings. On wet land planting is now often done in mounds, and it is found in large operations that the making of the mounds costs from 20*s.* to 25*s.* per 1,000, and planting by notch or circular spade costs about 9*s.* to 13*s.* Such planting therefore costs about 30*s.* to 35*s.* Planting with mattock or Schlich spade generally costs from 15*s.* to 25*s.* per 1,000 and pit planting costs more.

On small operations, which are typical of private estates, planting must be expected to cost considerably more and for such planting an addition of 20 to 50 per cent. must be made. Thus the cost of plants and planting may be as little as 15*s.*, or as much as 70*s.*, per acre, and it is useful to remember that the cost of a young tree put in the ground varies from approximately ¼*d.* to 1*d.* On private estates it generally costs from ½*d.* to ¾*d.*, and this figure should be borne in mind when the distance of planting is considered, as it

TABLE XXVI. *Analysis of costs of cultural operations: British Forestry Commission*

(*Forestry Commission Annual Report*, 1926–7, p. 15.) (*Costs in £.*)

		Plantations.								Nurseries.				
Year.	*Area planted. Acres.*	*Prep. of ground.* 1	*Drainage.* 2	*Fencing.* 3	*Planting.* 4	*Weeding and cleaning.* 5	*Beating up.* 6	*Protection.* 7	*Total.* 8	*New work.* 9	*Seed.* 10	*Labour and misc.* 11	*Total.* 12	*Grand total.* 13
1920	1,210	3,375	843	3,279	3,561	705	—	183	11,946	1,090	1,127	5,448	7,665	19,611
		2·8	*0·7*	*2·7*	*2·9*	*0·6*		*0·2*	*9·9*	*0·9*	*0·9*	*4·5*	*6·3*	*16·2*
1921	5,929	10,781	1,794	12,550	27,310	1,860	665	2,343	57,302	3,731	5,297	19,308	28,336	85,638
		1·8	*0·3*	*2·1*	*4·6*	*0·3*	*0·1*	*0·4*	*9·7*	*0·6*	*0·9*	*3·3*	*4·6*	*14·5*
1922	9,562	17,741	4,352	12,231	24,137	3,070	3,767	2,869	68,167	3,848	8,253	49,146	61,247	129,414
		1·9	*0·5*	*1·3*	*2·5*	*0·3*	*0·4*	*0·3*	*7·2*	*0·4*	*0·9*	*5·2*	*6·5*	*13·7*
1923	10,414	11,550	4,065	10,577	12,622	6,423	2,135	3,385	50,757	1,050	2,739	27,813	31,602	82,359
		1·1	*0·4*	*1·0*	*1·2*	*0·6*	*0·2*	*0·3*	*4·5*	*0·1*	*0·3*	*2·7*	*3·0*	*7·8*
1924	10,469	12,804	4,361	14,448	13,901	15,089	5,897	6,334	72,834	999	5,665	34,858	41,522	114,356
		1·2	*0·4*	*1·4*	*1·3*	*1·4*	*0·6*	*0·6*	*7·0*	*0·1*	*0·5*	*3·3*	*4·0*	*10·9*
1925	14,857	16,920	10,515	20,311	22,615	22,620	9,526	9,152	111,659	2,955	3,173	46,338	52,466	164,125
		1·1	*0·7*	*1·4*	*1·5*	*1·5*	*0·6*	*0·6*	*7·5*	*0·2*	*0·2*	*3·1*	*3·5*	*11·0*
1926	18,375	18,052	9,125	26,684	28,621	28,262	13,071	13,527	137,342	4,309	6,170	53,068	63,547	200,889
		1·0	*0·5*	*1·5*	*1·6*	*1·5*	*0·7*	*0·7*	*7·5*	*0·2*	*0·3*	*2·9*	*3·5*	*10·9*
1927	23,473	19,522	12,496	36,354	35,928	34,528	9,310	17,744	165,882	3,598	7,367	53,696	64,661	230,543
		0·8	*0·5*	*1·5*	*1·5*	*1·5*	*0·4*	*0·7*	*7·0*	*0·2*	*0·3*	*2·3*	*2·7*	*9·8*
Total	94,289	110,745	47,551	136,434	168,695	112,557	44,371	55,536	675,889	21,580	39,791	289,675	351,046	1,026,935
		1·2	*0·5*	*1·4*	*1·8*	*1·2*	*0·5*	*0·6*	*7·2*	*0·2*	*0·4*	*3·1*	*3·7*	*10·9*

Note.—The figures in italics are the amounts spent under each head divided by the area planted in each year. For fencing and planting these figures represent the cost per acre, but for other items various corrections would have to be made as the areas dealt with are not the areas planted in each year.

means that any thinnings, which can be sold standing for 2*d.* at 15 to 20 years old, have paid for themselves.

TABLE XXVII shows the costs per acre of plants and planting at various planting distances if the cost per 1,000 trees is 20*s.*, 60*s.*, and 100*s.* respectively. From this table it will be seen that wide

TABLE XXVII. *Cost of plants and planting at various planting distances.*

Planting distance. feet.	*No. of trees per acre.*	*Cost per acre if plants and planting cost per 1,000 trees.* 20*s.* £ *s.*	60*s.* £ *s.*	100*s.* £ *s.*
3 × 3	4,840	4 17	14 10	24 4
3½ × 3½	3,620	3 12	10 17	18 2
4 × 4	2,720	2 14	8 3	13 12
4½ × 4½	2,140	2 3	6 8	10 14
5 × 5	1,740	1 15	5 4	8 14
6 × 6	1,210	1 4	3 13	6 1
8 × 8	680	0 14	2 1	3 8

spacing is very much cheaper than close spacing and, unless early thinnings have a market value, spacing should be as wide as is silviculturally permissible. By combining this table with Table XXIV it is possible to assess the general range of the whole cost of planting, including fencing. This range is very wide, and there is a large scope for personal enterprise in reducing costs. On British private estates it is usual to regard £10 per acre as an average cost.

On the Forestry Commission areas[1] the average cost per acre of labour and material for planting only, i.e. preparation of ground, drainage, fencing, cost of plants and their insertion in the ground, and weeding for the first year, has been as shown in Table XXVIII:

TABLE XXVIII. *Cost of planting in Forestry Commission areas.*

Year.	*England and Wales.* £ *s.* *d.*	*Scotland.* £ *s.* *d.*	*Gt. Britain.* £ *s.* *d.*
1923	5 8 9	5 16 7	5 12 0
1924	5 4 6	6 5 1	5 11 8
1925	6 10 3	7 19 3	7 1 6
1926	5 16 10	7 10 3	6 7 7

The rise in cost from 1923/4 to 1925/6 is due to more careful methods of planting which it is found reduce the cost of ultimate establishment. If the cost of beating up and weeding until the plantations are established is included, the figures are considerably higher, and the average outlay up to 1926 on all the areas planted

[1] Seventh Annual Report of the Forestry Commissioners, 1927.

by the Forestry Commission from 1919 to 1926 was £8 14*s.* 5*d.* in England and Wales, £9 3*s.* 6*d.* in Scotland, and £8 17*s.* 4*d.* in Great Britain as a whole.

The cheapest form of planting may not be the most economic, and the choice of method can only be safely made when a number of test cases have been kept under statistical observation. Table XXIX refers to tests made with planting seedlings and transplants of Norway pine on the sand plains of Michigan.[1] The cost of plants per 1,000 was determined by nursery costings, and the cost of planting was approximately the same throughout. The data were worked up five years after planting. It appears from this table that 2-year seedlings are, in this case, the most economical form of plants to use; and that 2-year 1-year transplants are ultimately cheaper and more satisfactory than 1-year 1-year transplants.

TABLE XXIX. *Cost of planting seedlings and transplants of Norway pine.*

Class of stock.	*Cost of plants per 1,000.* $	*Cost of planting per 1,000.* $	*No. of plots.*	*Survival.* %	*Height. inches.*	*Final cost per 1,000.* $
1-yr. seedlings	1·90	3·01	7	70·0	14·6	7·01
2-yr. seedlings	2·41	3·01	7	84·9	20·0	6·38
1-yr. 1-yr. transplants	3·91	3·01	6	89·5	21·3	7·73
2-yr. 1-yr. do.	4·43	3·01	6	99·2	27·0	7·50

Examples of the cost of planting outside Britain.

SOUTH AFRICA.[2] In South Africa the costs depend on the kind of labour employed, and the following refer to piece-work rates for settlement workers who receive a normal wage of 6*s.* 4*d.* per day. The cost of clearing, preliminary to planting is generally from 10*s.* to £3 per acre. It is becoming the usual practice in South Africa to break the ground very thoroughly after clearing and before planting, and this is accomplished either by ploughing and harrowing twice or, where the land is too rough for a plough, by picking it with a mattock or pick. About 75 per cent. of the land is too rough for ploughing and has to be picked; the cost of planting at 6 × 6 ft. is then approximately as follows:

1st picking (with mattock)	£6 10*s.*	to £8 10*s.*
2nd " " "	3 0	4 10
Plants (30*s.* per 1,000)	1 16	1 16
Transport and planting	0 15	1 10
	£12 1*s.*	£16 6*s.*

[1] R. G. Shreck, *Journal of Forestry*, xxvi, 1928, p. 906.

[2] C. E. Legat, *Proc. and Res. Second Brit. Emp. For. Conf.*, 1923, p. 114.

If the land can be ploughed the cost is reduced to about £4 5s. to £6 per acre.

It should be noted that the ploughing or picking of the land is necessitated by the rank weed vegetation which otherwise suppresses the young trees. Where shade bearers are grown the ground should be fairly clean for the second rotation, and planting should then be far cheaper than it is for the first rotation. Following the practice of this chapter a large part of the above cost of planting should therefore be ascribed to the cost of land.

New Zealand.[1] Much enterprise has been directed in New Zealand towards reducing the costs of nursery work and planting with the result that the cost of making plantations has been approximately halved in recent years. The average cost of seedlings of *Pinus radiata*, the tree most often planted, is 9s. 7d. per 1,000 in the first year and 18s. in the second, and 1-year 1-year transplants cost 22s. per 1,000 to raise. Plants are notched in and a man can plant 1,000 to 1,200 per day in partly cleared hill country and 1,400 to 1,600 in well cleared country. Planting is generally at 8 × 8 ft., and with wages at 13s. 4d. per 8-hour day the cost of establishing coniferous plantations per acre in 1923 was as follows:

Clearing	8s.
Planting	7
Plants	21
Tools and equipment	5
Fencing and fire protection improvements	4
Superintendence, direction, &c.	5
Total	50s.

When the high wages are taken into account this cost is remarkably low, and it appears that other countries have much to learn from New Zealand.

India. No official report of the costs of planting in India is available, and no doubt the costs vary much from place to place. The following estimates,[2] however, which are apparently based on particular operations, give some indication of the cost where labour is cheap:

(1) Sal, Punjab irrigated plantations (1925/26), 21–24 Rs. (£1 11s. 6d.–£1 16s.)

(2) Teak, Burma, Tharrawaddy (1923), 20 Rs. (£1 10s.).
Taungyas, 15–20 Rs. (£1 2s. 6d.–£1 10s.).

(3) Casuarina, Bihar and Orissa (1924), 8 Rs. (12s.)
Madras (large transplants and watered), 30–60 Rs. (£2 5s.–£4 10s.)

(4) Bengal, Hill Taungyas (transplants), 51 Rs. (£3 16s. 6d.).

[1] L. MacIntosh Ellis, *Second Brit. For. Conf.*, 1923, p. 120.

[2] Editorial, *Indian Forester*, liv, 1928, p. 137.

FINLAND.[1] In Finland the commonest method of artificial regeneration is by direct seeding, and only small areas are planted. The cost of 2-year 2-year spruce transplants is about 10*s.* per 1,000, and the cost of planting by women about 5*s.* per 1,000. The usual planting distance is $1\cdot5 \times 1\cdot5$ metres, which is equivalent to 1,800 trees per acre, and the cost of plants and planting is about 30*s.* per acre. No fencing is necessary, and beating up is not generally attended to.

Direct seeding. This is generally cheaper than planting, but in Britain the method has proved to be too uncertain to practice on a large scale. In Finland, however, where young seedlings suffer less from enemies, direct seeding is the normal practice. Seed of pine costs about 3*s.* 9*d.* per lb. and $1\frac{1}{4}$ lb. are sown to the acre in plot sowing and 2 to 4 lb. in broadcasting. The digging of plots costs about 8*s.* 4*d.* per acre, and the total cost of plot seeding, including incidental expenses, is about 14*s.* per acre.

In South Africa direct seeding is not much cheaper than planting since the preparatory picking or ploughing of the land is found to be desirable under both systems, and the making of the plots for sowing costs from £1 10*s.* to £2 8*s.* per acre and is more expensive than the operation of putting the trees in the ground.

Natural regeneration. Where forests can be regenerated naturally by the seed falling from standing trees, this method is generally practised in preference to artificial regeneration. It is difficult, however, to assess the costs of natural regeneration, and it is only possible to lay down general principles by which the cost may be compared with that of planting or direct seeding.

For natural regeneration areas are either clear-felled and regenerated from seed in the ground or from seed blown on to them from neighbouring trees, or the areas are heavily thinned and regenerated by seed falling from the remaining trees (shelterwood). In either case regeneration is seldom complete until two seed years have occurred after felling, and the 'regeneration period' is thus shorter or longer according to the frequency of seed years. Thus in south Finland pine seed years occur every 3 to 5 years, but in north Finland only once in 10 to 30 years. Hence in the south the regeneration period is generally from 6 to 10 years and in the north from 20 to 60 years.[2]

When areas are planted with three-year-old trees in the same season as the land is cleared the plantation starts at three years old. These plantations have a considerable start on naturally regenerated areas and, under European conditions, this start is generally not less

[1] Hiley, *Oxford Forestry Memoir*, No. 8, 1928. [2] Ibid.

than 10 years. The loss of 10 years' growth of the forest is equivalent to a loss of 10 years' rent and 10 years' annual maintenance, and on good quality land this may amount to more than the cost of planting.

With a shelterwood system the mother trees put on increment during the regeneration period, and this increase in value may be set, in some measure, against the rent. It should be remembered, however, that unless they are increasing in value at a greater rate than, say, 5 per cent. per annum this growth only represents interest on the capital value of the trees. Also, with a shelterwood system the area has to be cut over at least twice, and this raises the cost of extraction which adds indirectly to the cost of natural regeneration.

In a country such as Finland which possesses a climate very favourable to natural regeneration, where, too, owing to the winter covering of snow and the numerous rivers, trees can be extracted without special roads and without damaging the young seedlings, natural regeneration is practised with the minimum of cost. But, owing to the greater rapidity and certainty of regeneration by direct seeding, the latter method is practised to an increasing extent in preference to natural regeneration. In areas such as south Germany, where both regeneration and extraction are more difficult, very elaborate methods are adopted to obtain regeneration (e.g. 'Blendersaumschlag' and wedge system). These methods not only entail very skilled supervision, but since trees have to be felled almost every year from the regenerating area, felling operations become very scattered and these systems are difficult to operate without an elaborate and expensive system of roads. Extraction is far cheaper if large continuous areas can be logged at the same time, and though this is possible in Finland with a system of natural regeneration it is not possible in Germany.

Artificial is far more certain than natural regeneration, and the latter system nearly always leaves blanks which have to be filled artificially.

To sum up the economics of natural as compared with artificial regeneration: natural regeneration is cheap on land of low rental in regions where it occurs readily; it is expensive on high priced land, especially if seed years are infrequent. In Switzerland and south Germany it is generally believed that trees grown from seed without any transplanting are healthier than transplanted stock, and natural regeneration or direct seeding are favoured for this reason; but there is very little, if any, reliable evidence in favour of this contention.

Natural regeneration has two further disadvantages: it necessi-

tates restocking the land with the same species as formed the previous crop when other species may be more profitable and a change of crop may be silviculturally desirable; it necessitates rotations which shall be at least long enough to enable the trees to bear good seed in considerable quantity which, in certain cases, is longer than the financial rotation.

The cost of annual maintenance (*e*). Annual maintenance is an inclusive term for all items of expenditure which are not included in the cost of land, the cost of planting, and the felling and extraction of saleable thinnings and timber. It includes all overheads such as expenses of office and supervision, rates, taxes, labour used in making unremunerative thinnings, road maintenance, fire protection and sundry other expenses. The net cost may be reduced by sundry items of income such as sporting or grazing rents, sale of minor products, &c.

A difficulty that always arises in the assessment of the annual cost of maintenance is that of distinguishing between capital expenditure and maintenance costs. The distinction has to be drawn in the same manner as in commercial accountancy, and the following examples will show the manner in which such difficulties are met. The building of workmen's cottages is a capital expense, but interest on capital, repairs, and depreciation should be charged against current expenditure. The building of roads is also a capital expense, though interest and repairs are charged against the annual account; in this case there should be no depreciation. Motor lorries and other machinery must pay interest, upkeep, and depreciation, and the rate of depreciation will depend on the expected life of the machines.

For convenience of calculation it is generally assumed that the cost of annual maintenance is constant throughout a rotation, whereas in practice it need not be. The cost is generally highest at the time when unremunerative thinnings have to be made and at the end of the rotation when roads have to be put into working order for purposes of extraction. The cost becomes rather more equally distributed if the expenses incurred in beating up and cleaning young plantations are included in *e* rather than *C*, and this method is preferable, though either is financially permissible.

The maintenance cost per acre depends on the size of the unit of management and on the manner in which it is managed. Large forest estates cost less per acre to manage than small estates because the salary of the manager and office expenses are spread over a greater number of acres, and large estates allow of more efficient division of labour. Intensity of management has, however, a weightier influence

on costs of management. Large natural forests worked on a long rotation require comparatively little supervision, and in Finland, where there is little need for special forest roads, the annual maintenance of state forests and forests owned by companies costs from *6d.* to *1s.* per acre per annum.

The actual cost of management per acre can only be estimated by an analysis of account books; but the following example shows the items that go to make up the annual cost on an English estate. It is assumed that all the woodland is managed intensively as plantations and that the average rotation is 50 years, which is probably sufficient for fast growing conifers. Under these conditions it is necessary to employ one labourer for every 100 to 150 acres, and if the maincrop timber is sold standing and no part of the labourer's time is devoted to a saw-mill one labourer to 150 acres is probably sufficient. At a wage of 35*s.* per week this man costs £91 per annum, so that the wage bill is about £60 per 100 acres. From this, however, may be deducted the labour costs of planting 2 acres annually, and the cost of cutting merchantable thinnings, since these costs are debited to the planting account or deducted from the sale value of the felled thinnings. The labour costs of planting 2 acres will, on a private estate, be about £18,[1] and the annual labour cost of thinning on the 100 acres will be, say, £30, which leaves £12 for incidental work to be included under *e*. On a small estate the woods are generally put in charge of a working forester whose salary depends on the area of woodland. If he receives £200 a year and is in charge of 1,000 acres of woodland this is equivalent to an added cost of £20 per annum per 100 acres. Office expenses may amount to another £10 and tools, &c., to £5 per 100 acres, making a total of £47 per 100 acres. There are always other items which should be debited to the forest account, such as interest on capital invested in forest roads, use of estate lorries, &c., and a share of the agent's time is necessarily spent in connexion with woodlands. On an estate which is managed in an enterprising manner a great deal of time and thought may be directed to the woodlands by the owner or agent, but this frequently gives an immediate return in the higher prices obtained for timber sold from the estate. The cost of annual maintenance also includes rates[2] and tithes (if any), but these can generally be balanced by shooting rents and, whether the shooting is let or held

[1] If the plants are raised on the estate nursery, so that the money spent in raising them is nearly all paid as wages.

[2] The derating of woodlands in Great Britain will eliminate this item from the cost of maintenance.

by the owner of the property, the woodlands account should be credited with this item.

For generalized calculations on the finance of estate plantations 12*s.* per acre per annum appears to be a reasonable figure to use for *e*, but, when calculations are made for particular estates, special values can be used.

It is impossible as yet to estimate a fair value for *e* for the Forestry Commission. Many of the overhead expenses of the Forestry Commission, such as the maintenance of head-quarter offices, are nearly as high now as they will be when the Commission controls ten times the area of forest which it owns at present. An expanding programme involves present expenditure which will be justified by future developments. In New Zealand the annual cost of management is assessed at 6*s.* per acre.[1]

[1] MacIntosh Ellis, *supra.*

VIII

THE INCOME FROM FORESTRY

Sources of income: lack of continuous records. The construction of money yield tables (Y_r and T_a): price-size gradient: efficiency coefficient: maincrop and thinnings: need for information with regard to probable future prices of exotics. Method of 'sortiments'. Prices of particular species.

Sources of income. The income from forestry is derived from the sale of (1) timber, (2) firewood and charcoal, (3) pulpwood, (4) poles and small produce from thinnings and coppice, (5) nursery seedlings and transplants, and (6) minor products, such as rosin, turpentine, lac, &c., greenery, Christmas trees, tree seeds, and other similar products. Rents for shooting and grazing, grass, minerals, gravel, &c., may also be an important source of income.

For the purpose of computing the returns which may be obtained from plantations the most important of these items of income are timber, firewood, pulpwood, and thinnings. 'Greenery' is seldom a major source of profit, but with certain species such as Lawson cypress a considerable income may be derived from cut branches in the early stages of growth, and, with spruce, selected young plants and tops of thinnings may be sold for Christmas trees. Nursery produce does not enter into the plantations account, but the sale of such produce may enable a nursery to be run at a profit. Shooting rents, &c., are credited to the general maintenance account and serve to keep down the cost of annual maintenance.

There are very few continuous records of the income derived from individual plantations, so that we have to rely principally on estimated returns based on statistics of volume production and prices. This is particularly the case in Britain where many species are now being planted for which no regular markets have been established. This is less to be regretted than may appear at first sight because through the long period of a forest rotation money values are certain to change and the quotation of money yields from thinnings fifty years ago would be of little assistance in prognosticating returns from plantations being made now. Compared with prices volume yields are stable, and when looking to the future it is far safer to assess income from volumes, which can be estimated with reasonable accuracy, together with current prices, than to calculate from lump sums which have been derived from felling known areas in the past.

The assessment of future returns must be based on volume yield tables, and calculations are entirely dependent on the existence of such yield tables. British yield tables have so far only been constructed for conifers, and for broad-leaved species we are dependent on continental tables the applicability of which is open to question. The British yield tables constructed by the Forestry Commission are reproduced in the appendix.

The construction of money yield tables (Y_r and T_a). Money yield tables are tables, constructed from volume yield tables, in which the yields are expressed in the form of money instead of volume. Money yields depend on the volume obtained at any age and the price per cubic foot at which it can be sold, so that from any given volume yield table various money yield tables may be constructed by the introduction of different prices. Also each quality class of a volume yield table will give a different set of money yield tables.

In constructing a money yield table for a given species on a given site it is necessary to know (1) the quality class of the site for the species in terms of some volume yield table, and (2) the prices per cubic foot that may be expected for each size of tree of the species under consideration. For this purpose present prices are generally adopted but, if it is thought that markets will change, other prices may be inserted, or it may be assumed that prices will rise at a certain rate, e.g. 1 per cent. per annum.

The quality class of a site can be most easily ascertained by the measurement of existing stands of known age. The most important single factor for determining the quality class of an existing stand is the relation between the average height of the stand (or the average height of the dominant trees) and the age, and many volume yield tables are accompanied by graphs showing the rate of height growth of each quality class. As no piece of bare ground is exactly comparable with that on which measurable stands exist it is necessary for the observer to use his discrimination in selecting stands for comparison; however, a practical forester gets to know the quality class of tried species that he may expect in various parts of the estate he has to manage.

The determination of price is generally more difficult than that of quality class. The sale price per cubic foot is higher for large trees than small, and the simplest way of showing this relationship is to draw a graph connecting the price per cubic foot with the number of cubic feet in the average tree. Such a graph is called a *price-size graph* and the curve itself may be called the *price-size gradient*. For some species and in some localities the price-size gradient is steep,

i.e. large trees sell for much more per cubic foot than small trees, whereas in others, e.g. in regions governed by a pitwood market, the gradient is flat, since large trees sell for little more per cubic foot than small ones.

The price per cubic foot is determined not only by the species and volume per tree, but also by its diameter; and often a short thick-boled tree may fetch more than a tall thin tree of the same volume. But the relationship of price per cubic foot to girth is very difficult to introduce into a yield table for the reason that volume yield tables do not supply the necessary information.

On large estates, where timber sales are frequently held, price-size graphs may be constructed from local experience. All that is needed is the number of trees, total volume, and total price for each sale, since from these amounts both the average size of tree and the price per cubic foot can be determined. If the axes of a graph are drawn as in Fig. 12, with one co-ordinate representing the volume per tree and the other the price per cubic foot, dots can be marked representing the result of each sale. A smooth curve can then be drawn through these points to represent the price-size gradient. Such data, however, are not frequently available and, when they are absent, an approximate price-size gradient can generally be drawn by an experienced forester from his own knowledge of prices or with the help of a timber merchant. It must be remembered, however, that the price of timber is also dependent on its position, and where extraction is difficult lower prices will be obtained than in plantations near a good road.

From a volume yield table and a price-size graph a money yield table is constructed. The method will be clear from a study of an example such as that in Table XXX, which is a money yield table for European larch, Quality II (British Yield Tables), with prices taken from the graph in Fig. 12. The columns *a*, *b*, and *c* are taken direct from the volume yield table, and the volume per tree (*d*) is calculated from *b* and *c*. The price per cubic foot (*e*) is read off from the graph, and the value per acre (*f*) of the main crop is found by multiplying the volume by the price per cubic foot.

It is now necessary to introduce an *efficiency correction*. The volume yield tables are constructed from fully stocked plantations, and in practice no large area is ever fully stocked; there will also be losses from heart-rot and other diseases as well as space taken up by rides. In a well-managed forest the total area of roads and rides may be about 10 per cent., but not all this is lost to forestry as the trees on the sides of the rides grow larger than the average owing to their

receiving more light and moisture; and the rides do not cost anything to plant, while their upkeep is charged to the cost of annual maintenance.

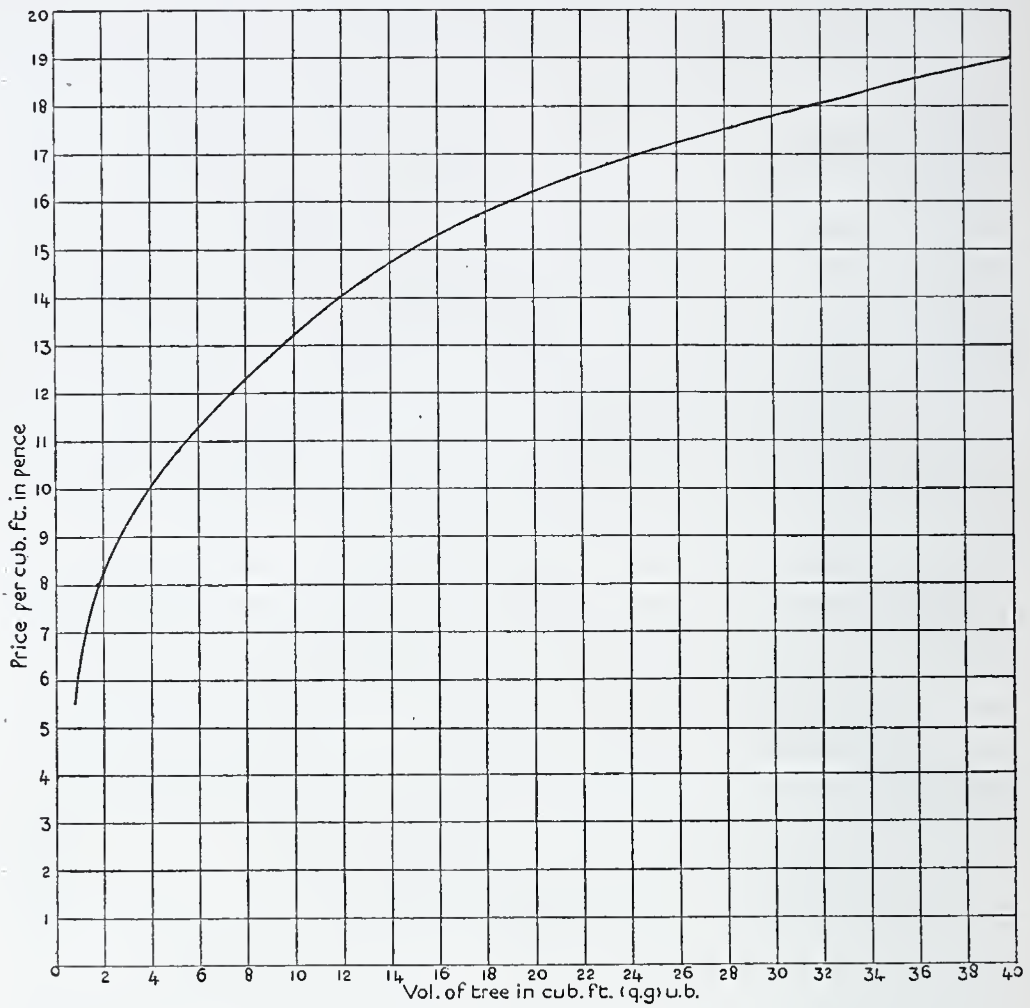

FIG. 12. Price-size gradient for European larch.

(*Note.* These prices are rather higher than can be obtained in 1929 except in very favourable localities.)

In intensively managed forests losses are chiefly due to fire, wind- and snow-break, and fungi and insects, and the average of the losses will depend very much on locality, species, and skill in management. In the absence of reliable statistics it is usual to allow for a loss of 30 per cent., which is equivalent to a 70 per cent. efficiency. For Britain this is probably a generous estimate, but it is wise to err on the conservative side.

The value of thinnings is calculated in the same manner as that

TABLE XXX. *Money yield table for European larch, Quality II.*
(Poor market for small thinnings.)

For. Com. Bull. 10, 1928.

Age.	*Main Crop.*						*Thinnings.*				*Final Yield.*
	No. of Trees.	*Cubic Feet.*		*Price. Pence.*	*Value. £*	*Value less 30 %. £*	*No. of poles or cub. ft. Total.*	*Height or volume. per tree.*	*Price. Pence.*	*Value. £ (T_a)*	*Value. £ (Y_r.)*
Years.		*Total.*	*Per tree.*								
a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*j.*	*k.*	*l.*
							poles.	*aver. hgt.*	*per pole.*		
15	—	—	—	—	—	—	300	15	2	2·5	—
20	1,160	900	0·8	5·5	20·6	14·4	200	25	3	2·5	16·9
25	850	1,520	1·8	8·0	50·7	35·5	310	32	4	5·2	40·7
30	640	2,100	3·3	9·5	83·1	58·2	210	40	6	5·2	63.4
							cub. ft.	*vol. per tree.*	*per c.f.*		
35	500	2,600	5·2	10·8	117	81·9	180	1·3	5·0	3·8	85·7
40	410	3,050	7·4	12·0	152	106	200	2·2	6·3	5·2	111
45	350	3,410	9·7	13·1	186	130	220	3·7	7·3	6·7	137
50	310	3,700	11.9	14·1	218	152	240	6·0	8·4	8·4	160
55	275	4,000	14·5	14·9	248	174	250	7·1	8·8	9·2	183
60	240	4,250	17·7	15·7	278	195	260	7·4	9·0	9·8	205
65	210	4,510	21·5	16·5	310	217	265	8·8	9·5	10·5	227
70	190	4,760	25·0	17·1	339	237	260	13·0	10·8	11·7	249
75	175	4,960	28·3	17·6	364	255	230	15·3	11·5	11·0	266
80	165	5,170	31·3	18·0	388	272	180	18·0	12·0	9·0	281

of the main crop, but in this case full efficiency may be allowed since many of the factors which reduce the efficiency of the maincrop, such as wind, snow, and some diseases, actually increase the number of thinnings which are removed. Small thinnings are generally sold, not by the cubic foot, but by the pole, and when sold in this way the price may be much higher than that which is estimated from their volume. In Table XXX prices have been entered in this way for thinnings up to 30 years, but it should be noted that where the market for stakes and poles is good prices three times as high as those quoted may be obtained. Also in the British Yield Tables no estimate is given for thinnings of this quality of larch at a lower age than 25 years and, as the early thinnings of larch have nearly always a very considerable value, numbers have been put in from estimates based on the number of trees planted. If the planting distance is 4½ by 4½ ft., 2,150 trees are planted to the acre of which some 1,700 may be expected to survive. It should be noted that during the early years plantations of larch and Douglas fir may have to be thinned every three years, and the five-yearly intervals of the yield tables are not strictly applicable. However, the assumption of five-yearly thinning simplifies calculations and does not give rise to appreciable error.

The value of the final yield (column *l*) is the sum of column *g* and column *k* for any year. Using the ordinary symbols the value of the thinning in any year a is T_a, and the value of the final yield in the year r is Y_r.

This method of estimating the future income from plantations can only be applied when volume yield tables are available and timber prices are known, and in the absence of such data any estimates are entirely speculative. In many countries such as Australia, New Zealand, South Africa, and especially in Britain, exotic species are being planted extensively, and the data necessary for estimates of income are only gradually being collected. In such cases the construction of volume yield tables should be pressed forward with the utmost zeal, and even approximate tables are of great value. The estimation of prices is, perhaps, more difficult than the construction of yield tables, for, until considerable quantities of a timber are available for the market and until the wood has been tested for the various purposes to which it may be put, no real market price exists. One of the functions of timber-testing laboratories is to experiment with little-known timbers and to assess their value for various purposes in comparison with timbers at present on the market, and in order to avoid a great deal of delay in estimating the

possible returns from planting little-tried species it is very desirable that these timber-testing departments should supply this information as soon as timber of the species in question, grown under plantation conditions, can be obtained.

An example of a tree which is being cultivated to an increasing extent in Britain, though no estimate of its profitableness can yet be made, is *Thuja plicata*, the western red cedar. It is known that the timber of this tree is very light in weight and very resistant to rot, and in British Columbia it commands a very good market for shingles, telegraph poles, floats, and internal decoration. In Britain the young thinnings yield stakes and poles which are probably as valuable as larch, and for this reason the tree is a good speculation in any district where the market for larch thinnings is active. The timber has also been tried for gates and other estate purposes, but we urgently need more information about its possible uses and its real value in comparison with other timbers. Its volume increment per acre is considerably greater than that of European larch, but less than that of Douglas fir, and the tree has silvicultural attractiveness.

METHOD OF 'SORTIMENTS'. The method of estimating yields by means of a price-size gradient is not the only one; in many countries standing timber is classified into qualities for purposes of sale, and the prices of these qualities are used in the construction of money yield tables. Thus Schwappach[1] uses the Prussian timber classes or *sortiments* for Scots pine with the following prices:

Timber Class I, over 2 cub. metres	price 22,00	mks.	per m³.
,, ,, II, 1 to 2 ,, ,,	,, 19,00	,,	,,
,, ,, III, 0·5 to 1 ,, ,,	,, 13,00	,,	,,
,, ,, IV, up to 0·5 ,, ,,	,, 10,00	,,	,,
Pitwood	9,00	,,	,,
Firewood: split billets	7,14	,,	,,
,, round wood	4,29	,,	,,
,, faggots	1,00	,,	,,

The volume yield of maincrop and thinnings at each age is not only estimated as a whole but is divided into percentages of each *sortiment*, and the money yield at each age is calculated from these figures.

Where, as in the Prussian forests, definite *sortiments* are recognized by the timber trade an average price for each *sortiment* can be calculated from records of sales in the state forests, and this method can be applied with considerable assurance. The method is also the most satisfactory when timber of different sizes is put to different

[1] *Die Kiefer*, Neudamm, 1908.

uses; as, for instance, when large trees are sawn and smaller ones sold for pitprops or pulpwood. The British yield tables, however, only give average sizes, and when these tables are used the price-size gradient provides the most convenient method of transforming from volume to value.

Price of particular species. The standing prices that may be obtained per cubic foot for any species depends on a large number of factors. Some species are more valuable than others; a large tree is generally worth more than a small tree of the same species; straightness and freedom from knots increase price; distance from market, distance from road and rail, and the nature of the ground over which extraction has to take place, will also affect the price. Under these circumstances no fixed price can be quoted for any species, but the student who has had no experience in selling timber may find the following figures useful. They may be accepted as fairly representative standing prices for Britain, but considerable deviations occur from place to place. The figures refer to the price per cubic foot, quarter girth, for trees of about 20 c.f. per tree.

Scots pine	8*d.*	Ash	2*s.* 3*d.*
Larch	1*s.* 0*d.*	Beech	10*d.*
Spruce	6*d.*	Elm	8*d.*
Oak	1*s.* 3*d.*	Poplar	8*d.*

At 40 c.f. per tree, oak may be worth double this price, and special qualities of ash will be worth much more than the figure quoted.

Coppice wood is generally sold by the acre. The most valuable coppice species is sweet chestnut, the price for which may be as high as £40 per acre on a 9-year rotation;[1] ash coppice will generally find a market, but hazel coppice and oak coppice, the two kinds which are commonest in England, are often scarcely saleable, and the average price is probably not more than £2 to £3 per acre.

[1] Actual prices per acre for which a small area of chestnut coppice was sold in Sussex, from the middle of last century onwards, are given by T. Roberts, *Quart. Journ. of Forestry*, 1929. The price rose from £20 in 1850 to £36 10*s.* in 1868, when there was a keen demand for hop poles. As this demand fell off the price was gradually reduced to £6 in 1906/13. In 1905 the industry of chestnut pale fencing was established in the district and in recent years prices have risen, in some instances to over £40 per acre.

IX

METHODS OF ESTIMATING PROFITABLENESS IN FORESTRY

Classification of methods. Method of simple interest. With compound interest: the financial yield. The financial yield formula. The use of schedules for computing financial yields. The indicator graph: an example for European larch, Quality II. Chapman's financial yield formula. The uses and limitations of the financial yield method.

Classification of methods. Owing to the long period which elapses between the initiation and marketing of a forest crop the estimation of the profitableness of the undertaking is a matter of very special difficulty. Various methods have been used, and none of them is satisfactory for all purposes. Further, if the chief goal of the forester is profit, he requires a method which will indicate the most profitable method of working; but, since different methods of calculation show widely divergent systems of management to be the most profitable, executive officers may justly complain of confusion, and in the last few decades this confusion has led to bitter controversy. A careful analysis of the methods more commonly employed forms, therefore, a necessary introduction to the subject.

The methods of estimating profitableness may be classified as follows:

I. Methods involving interest on capital.
  1. With simple interest: based on the relation of the net annual income to the capital value of the forest.
  2. With compound interest: using the rate of interest as a basis of estimate, i.e. the *financial yield*,
     (*a*) based on a completed transaction;
     (*b*) based on expectations with the help of yield tables.
  3. With compound interest: the rate of interest being fixed,
     (*a*) methods of *soil expectation value* and *soil rental*;
     (*b*) method of profit.
  4. The method of *indicating per cent.*: used for estimating the rate of increase in value of a stand during a period of its growth.

II. Method not involving interest on capital.
  The method of *forest rental* or net income from an area of forest without regard to its capital value.

Method of simple interest. The principle of this method is that if the net annual income (I) from a forest is known, and if the capital

value (C) of the forest is also known, then the rate of interest calculated from the formula $p = \frac{I}{C} \times 100$ is a fair expression of the profitableness of the forest.

The method is theoretically simple and is therefore attractive. However, it involves very difficult valuations and for this reason it has seldom been applied in practice.

Recent work by von Spiegel[1] has shown that, if forests were periodically valued under some definite system, the method could be made the basis of financial administration. The theory of the method can be explained most simply in relation to an ideally normal forest.

The simplest case of an ideally normal forest is an area of r acres worked on a rotation of r years so that at the beginning of each growing season one acre is just planted, one is 1 year old, one 2 years old, and so on up to $r-1$ years. During the year one acre of mature timber will be felled (value Y_r) and one acre will be thinned at each thinning age ($T_a + T_b + T_c + \ldots$); in the same year one acre will be planted (at cost C) and r acres will bear the cost of annual management (e). Thus the net income is $I = Y_r + \Sigma T_a - C - re$.[2]

The capital on which this income is obtained is the value of r acres of land, plus the value of all the growing-stock, plus the value of roads, buildings, &c. The land can be valued at the market price, and mature timber at its standing value; immature timber may have no realizable value though it has cost money to raise, and it has a value to the forester as it will become saleable in the future; thus, some method of evaluating it has to be adopted.

An immature plantation may be valued from either of two points of view. The value may be based on the costs which have been incurred in producing it, compound interest being added to all costs from the time when the money was spent to the time of valuation; this is the *cost value*. Or the value may be based on the anticipated returns which will be received from the plantation, all returns being discounted from the time when it is expected that they will be received to the time of valuation; this is the *expectation value*. The cost value is based entirely on past expenditure, the expectation value entirely on future yields. Both methods involve the use of some arbitrary rate of interest, in the first case for compound interest and,

[1] Frhr. Spiegel von und zu Peckelsheim, *Praktische Waldwertrechnung auf wirtschafttheoretischer Grundlage*, Hanover, 1926.

[2] Σ is a mathematical symbol for the sum of a number of similar terms; thus ΣT_a stands for $T_a + T_b + T_c + \ldots T_q$, i.e. the sum of the values of all the thinnings.

in the second, for discount; and the estimated value of the plantation will depend on the rate of interest which is used. A high rate of interest makes for a high cost value and a low expectation value, and a low rate of interest makes for a low cost value and a high expectation value.

The two methods and the difficulty of choosing a suitable rate of interest are discussed on pp. 168–70; but von Spiegel recommends a simple method of avoiding controversial difficulties of this nature, and suggests the use of a graph for determining the values. Thus, if the initial cost of land and planting is £12 per acre, he puts the value in the first year at £12 (i.e. cost value); if the plantation first becomes reasonably merchantable at 40 years and is then worth £45 per acre, he puts in this value at 40 years. He connects the two by a line, which may apparently be a straight line though it should more accurately follow a compound interest curve, and reads off the value at intermediate ages on this graph.

In this manner all land and growing stock can be valued, and, if necessary, the value of roads, buildings, machinery, &c., can be added, and so the total capital value can be arrived at. The net income is, in practice, a more difficult figure to assess. The equation given above (p. 132) is true only for an ideally normal forest, whereas no forest is actually normal. Every year a certain amount of timber may be cut and a certain book income recorded, but this income may be earned by cutting more or less than the actual increment, and at the end of a year the value of the growing stock that remains may be less or more than it was at the beginning. If net income is to be used as a test of management it must include any increase in capital which may have accrued during the year, or take account of capital depreciation.

It is thus clear that the net income can be determined only if frequent valuations of capital are made, and the necessity for frequent valuations is the chief difficulty presented by this method of assessing profitableness. Von Spiegel and others have suggested quick methods of valuation which may be sufficiently accurate for this purpose, and there is no doubt that, whatever method of assessing profitableness is used, frequent valuations are very useful in controlling management. A further difficulty, which has not yet been mentioned, arises from the fact that the value of a forest may change, not only on account of increment in timber volume and quality, but through variations in the market price of timber. If one valuation is made during a period of high prices and the next during a period of low prices the capital depreciation in the period may be greater

than the actual money income. But this difficulty may be partly obviated by using fixed prices for timber over fairly long periods.

The method described in this section is most useful when thorough financial control is aimed at. It enables a fair comparison to be made between the profitableness of a compartment or *revier* containing an excess of mature timber with one which contains no mature timber. In the first case the net receipts may be very large and in the second they may be nil, but by periodic valuations it may be shown that the second has been more profitably managed than the first.

The method is of less use for the solution of the many problems of silviculture and management. Von Spiegel has worked out tables showing the rate of interest that may be obtained on various rotations with the species most commonly grown in Germany;[1] but in deciding questions of rotation, choice of species, thinning grade, &c., it is simpler to use the method of financial yield explained in the next section. The simple interest method is applicable chiefly to forests which are going concerns: the financial yield method to individual plantations.[2]

With compound interest: the financial yield. In the previous method the conception of profitableness was based on the year's working: in this and remaining methods it is based on the relation between the sale value of forest products and the costs of production. Since costs of production are incurred over many years in forestry they can be brought into relation with income only through the medium of compound interest, and interest on capital must be regarded as one of the costs of production. In nearly every case it is by far the largest item of cost, as is shown in the following instance. On an acre of first quality larch plantation, grown on a rotation of 80 years, the total expenditure on land, material, labour, and management may be £68, spent at various times during the rotation. The total receipts, from the plantation for timber and thinnings will approximate, at present prices, to £460, and the rate of interest obtained will be about 4 per cent. Thus if interest is reckoned at 4 per cent. the total amount charged for interest will be £460 − £68 = £392. At 3 per cent. the interest would have amounted to about £120 and at 5 per cent. to about £890. Thus in estimating costs of production the rate of interest is a factor of overwhelming importance; at the same time, if other costs could be reduced the

[1] Some of these are reproduced on p. 214.

[2] For further references to literature on this subject see Godbersen, *Theorie der forstliche Oekonomik,* Neudamm, 1926, and Hiley, *Forestry,* vol. i, 1927, p. 106, note 4.

amount charged for interest at any given rate would automatically be reduced in proportion.

The term *financial yield* is applied to the rate of interest which is actually earned by a plantation [1] or series of plantations on the money invested in making them. It is the same thing as the 'mean annual forest per cent.' of the earlier text-books, an expression which is now more useful as a description than a term. It has the advantage of being the simplest single criterion of profitableness in forestry and the one which can most easily be compared with profitableness in other industries. It is, however, difficult to calculate, and labour-saving devices are essential if extensive computations are involved.

As the conception of the financial yield is frequently misunderstood an example will be useful. 'National Saving Certificates' are a form of investment in which money is allowed to accumulate at compound interest for six or ten years. If a man buys a certificate for 16*s.*, and at the end of ten years realizes 24*s.*, then the rate of interest he has received is given by the equation

$$16 \times 1\,.\,0p^{10} = 24$$

from which $p = 4{\cdot}14$ per cent. The *financial yield* of the investment is, therefore, 4·14 per cent.

Investments in plantations are much more complex than this since money is paid out for land and planting in the first year and for management in each subsequent year; and income is derived from thinnings at various dates as well as a larger sum at the end of the rotation. Let us suppose that a man arranges for a bank overdraft, on which he pays 5 per cent. interest, and that by drawing cheques as required he buys land and plants it and pays for annual management; the interest on the overdraft is paid for by increasing the debit account so that the overdraft grows by compound interest; when he derives a profit from thinnings he pays this into the account and so lessens his overdraft; at the end of the rotation he sells the final crop and the land and pays the receipts from these into the bank. Let us further suppose that at the end of the transaction he is all square, so that the receipts from the final yield and sale of land have been just sufficient to pay off the overdraft. Then the plantation will have paid 5 per cent., and if the owner had financed it with his

[1] Strictly speaking a plantation is an area of forest initiated by planting. In this chapter, however, the word is used to cover any more or less even-aged area of forest by whatever means it has been initiated. It is the simplest unit of an organized forest.

own money he would have received 5 per cent. compound interest on all capital while it was invested in the enterprise. Then the *financial yield* would have been 5 per cent.

The method of financial yield may be applied to completed transactions when the costs of formation and tending plantations as well as the receipts up to a final felling are known. It is only in rare instances that such data are available, and these instances are mostly provided by very short rotations which are not typical of forestry. An interesting instance, however, of the application of this method to the teak forests of Nilambur is given on p. 147.

The method is usually applied to expectations based on experience, the costs being estimated from the costs of similar operations in the past and the income from yield tables which have been found applicable to the situation with market prices at present in vogue. As prices and costs are never constant during the long period of a rotation the results of the calculations are likely to differ considerably from the results actually achieved in practice and, owing to the tendency of timber prices to rise, the practical results are likely to be more favourable than the estimates based on present prices. In this respect the calculations are somewhat unreal, and they are frequently criticized as being only paper figures. But it should be remembered that in every well-managed business the probable costs and returns have to be computed for any progressive step before that step is taken, the financial attractiveness of various alternatives has to be assessed, and the greater the accuracy of these computations the more the business is likely to prosper. Such computations are all paper figures until a plan is put into operation, and it is on the accuracy of the paper figures that the success of the business depends.

The use of estimated financial yields is not so much to show the rates of interest that may be earned on any system of forestry—since the estimates will be largely upset by future changes in timber prices—as to form a basis for comparing the profitableness of various systems. Though timber prices change, the relative prices of various timbers generally remain more or less constant, and if one species, *A*, is estimated to earn a higher financial yield than another species, *B*, at present prices, then it is highly probable that if prices alter the price of *A* will still bear about the same relation to the price of *B*, and the cultivation of *A* will still be more remunerative than the cultivation of *B*. Consequently the method of the financial yield, like all compound interest methods, is chiefly used for the purpose of selecting between two alternatives.

The financial yield formula. The following symbols are here employed as in all other chapters in this book:

S = the market price of the land (see p. 109);
C = the cost of planting in the year 0 (see p. 111);
e = the cost of annual management (see p. 120);
$T_a, T_b \ldots T_q$ are the standing values of thinnings in the years $a, b \ldots q$;
Y_r = the standing value of the final yield in the year r.

All these amounts are expressed in terms of unit area, the acre in Britain, the hectare on the continent.

r = the rotation in years;
p = the rate of interest it is desired to find, i.e. the financial yield.

For the manner in which these amounts may be estimated reference should be made to chapters vii and viii.

The financial yield is by definition the actual rate of interest obtained on the capital invested in a plantation over the period of a rotation. Therefore, if all expenditure on the one hand and all income on the other are carried forward to the end of the rotation at p per cent. compound interest, then the two amounts will be equal. The costs are:

S incurred in year 0: this carried forward to year r
$$= S \times 1{\cdot}0p^r.$$
C incurred in year 0: this carried forward to year r
$$= C \times 1{\cdot}0p^r.$$
e incurred in each year from year 1 to year r[1]: this carried forward to year $r = e(1{\cdot}0p^{r-1} + 1{\cdot}0p^{r-2} + \ldots + 1{\cdot}0p + 1)$
$$= e\frac{1{\cdot}0p^r - 1}{1{\cdot}0p - 1}$$
$$= \frac{e}{{\cdot}0p}(1{\cdot}0p^r - 1).$$

The total costs carried forward to the year r are, therefore,
$$S \times 1{\cdot}0p^r + C \times 1{\cdot}0p^r + \frac{e}{{\cdot}0p}(1{\cdot}0p^r - 1).$$

The items of income are:

T_a in the year a: this carried forward to year r = $T_a \times 1{\cdot}0p^{r-a}$
T_b „ „ b: „ „ „ = $T_b \times 1{\cdot}0p^{r-b}$
T_q „ „ q: „ „ „ = $T_q \times 1{\cdot}0p^{r-q}$
Y_r „ „ r: „ „ „ = Y_r.

[1] In order to facilitate calculations it is assumed that e is incurred at the end of each year.

The land itself remains as an asset at the end of the rotation, and it will be assumed that at the end of the rotation this has the same value as at the beginning, viz. S.

Therefore, the total income carried forward to the year r is

$$T_a \times 1{\cdot}0p^{r-a} + T_b \times 1{\cdot}0p^{r-b} + \ldots + T_q \times 1{\cdot}0p^{r-q} + Y_r + S,$$

or

$$Y_r + S + \Sigma T_a \times 1{\cdot}0p^{r-a}.$$

Since p is the rate of interest that makes the costs and income equal when carried forward to the end of the rotation,

$$S \times 1{\cdot}0p^r + C \times 1{\cdot}0p^r + \frac{e}{{\cdot}0p}(1{\cdot}0p^r - 1) = Y_r + S + \Sigma T_a \times 1{\cdot}0p^{r-a}.$$

$$\therefore S(1{\cdot}0p^r - 1) = Y_r + \Sigma T_a \times 1{\cdot}0p^{r-a} - C \times 1{\cdot}0p^r - \frac{e}{{\cdot}0p}(1{\cdot}0p^r - 1).$$

$$S = \frac{Y_r + \Sigma T_a \times 1{\cdot}0p^{r-a} - C \times 1{\cdot}0p^r}{1{\cdot}0p^r - 1} - \frac{e}{{\cdot}0p} \quad \ldots\ldots \text{ I.}$$

All the terms in this equation are assumed to be known with the exception of p; it is therefore necessary to solve the equation for the unknown, p. Owing to the high powers of p involved in the equation this cannot be done directly, but it may be done indirectly by inserting various values of p in the expression on the right hand of equation I and finding by interpolation the value which makes this expression equal to the known value S. Thus in calculations dealing with a quality I larch plantation worked on a rotation of 50 years it was found that the following values of p made the expression on the right equal to the amounts shown:

if $p = 2$	expression	on right	$=$ £127·8
„ $p = 3$	„	„	$=$ £57·8
„ $p = 4$	„	„	$=$ £26·6
„ $p = 5$	„	„	$=$ £10·3
„ $p = 6$	„	„	$=$ £1·1
„ $p = 7$	„	„	$= -$£4·3

These figures are graphed in Fig. 13, and from this graph may be read off the financial yield which corresponds to any cost value of the land. Thus, if $S =$ £5, the financial yield is 5·5 per cent.; but, if $S =$ £20, the financial yield is only 4·3 per cent.

The use of schedules for computing financial yields. For computing a single value of a financial yield it is necessary to test several values of p in equation I. This is very laborious, but the work can be greatly reduced by the use of schedules made out in the following manner.

Equation I may be written:

$$S = \left[\left(\frac{1}{1{\cdot}0\,p^r - 1}\right) Y_r + \left(\frac{1{\cdot}0\,p^{r-a}}{1{\cdot}0\,p^r - 1}\right) T_a + \left(\frac{1{\cdot}0\,p^{r-b}}{1{\cdot}0\,p^r - 1}\right) T_b + \ldots\right]$$

$$- \left[\left(\frac{1{\cdot}0\,p^r}{1{\cdot}0\,p^r - 1}\right) C + \left(\frac{1}{{\cdot}0\,p}\right) e\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{II.}$$

For any given rotation and any given value of p the amounts in the round brackets are constant, and the amounts outside the round brackets are the actual items of income and expenditure. In the schedules, which are now used at the Imperial Forestry Institute, Oxford, the amounts in round brackets are printed for values of p ranging from 2 to 10 per cent. One of these schedules is reproduced in Table XXXI, p. 141. This is a schedule for a rotation of 50 years, and each column represents the values of the constants for a particular rate of interest. Thus, following down the second column (2 per cent.),

$$\frac{1}{1{\cdot}02^{50} - 1} = 0{\cdot}5910 \qquad \frac{1{\cdot}02^{50}}{1{\cdot}02^{50} - 1} = 1{\cdot}59$$

$$\frac{1{\cdot}02^{35}}{1{\cdot}02^{50} - 1} = 1{\cdot}183 \qquad \frac{1}{0{\cdot}02} = 50{\cdot}0$$

$$\frac{1{\cdot}02^{30}}{1{\cdot}02^{50} - 1} = 1{\cdot}071$$

The printed part of the schedule is here reproduced in upright type; in using the schedule figures are entered as shown in italics. In the first column are inserted the estimated amounts of income (in this case for larch quality II, see Table XXX, p. 127) and costs. By means of a slide rule these items are multiplied by their respective multipliers, the process being very rapid if each item (e.g. 160 for Y_{50}) is multiplied by its appropriate series of multipliers across the page before proceeding to the next item. The amounts down to X (which are all income) are added together, and this total represents the summation of the first square bracket in equation II. The next two items (Z) are also added together and represent the costs (other than land), or the sum of the second square bracket in equation II. By subtracting Z from X we obtain the test value of S for each rate of interest. These test values can then be graphed as in Fig. 13 to find the actual financial yield corresponding to any land value, or the rate may be read off approximately by inspection.

In equations I and II the cost of the land is put in as a capital value. In many instances, however, land is either rented for forestry or a landowner plants land which he could let for agricultural purposes. The rent corresponding to a land value of S is $S \times 0{\cdot}0p$, or, since land values are generally expressed in pounds and rents in

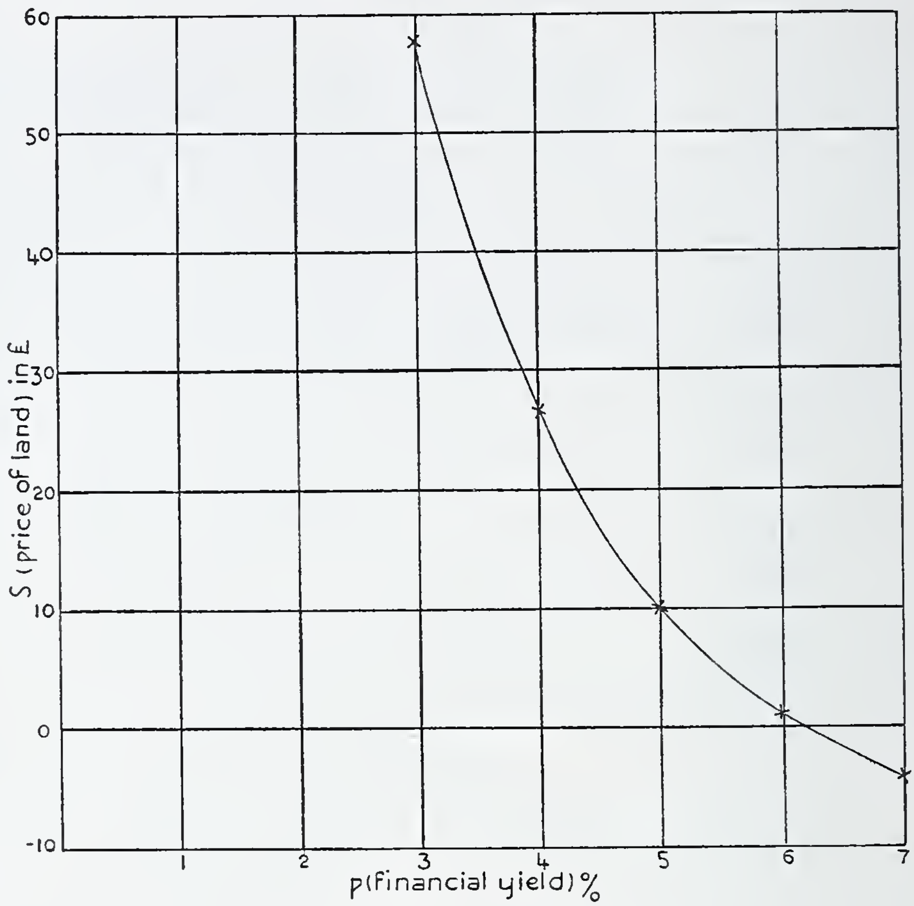

FIG. 13. Graphical solution of financial-yield equation.

shillings, the latter may be expressed in shillings as $S \times 0{\cdot}0p \times 20$. This value is shown in the bottom line of the schedule, and the financial yield earned may be estimated, as before, by interpolation.

In addition to saving time these schedules provide an analysis of the influence of each category of income and expenditure. To appreciate this it is necessary to investigate the meaning of each term in the summation, and, as an example, the item of £2·5 for a thinning in the year 15 will be considered. In the column for 4 per cent. this sum is multiplied by 0·646 or $\dfrac{1{\cdot}04^{50-15}}{1{\cdot}04^{50}-1}$. This multiplier is equal

TABLE XXXI. *Calculation of financial yield.* Rotation, *50 years.* Money Yield Table Reference, *B.Y.T. 1928, poor market for thinnings.* Species, *European Larch.* Quality *II.*

	£	2%		3%		4%		5%		6%		7%	8%	10%
Y_{50} =	*160*	0·5910	*94·6*	0·2955	*47·3*	0·1638	*26·2*	0·0955	*15·3*	0·0574	*9·2*	0·0351	0·0218	0·0086
T_{15} =	*2·5*	1·183	*3·0*	0·832	*2·1*	0·646	*1·6*	0·527	*1·3*	0·441	*1·1*	0·375	0·322	0·241
T_{20} =	*2·5*	1·071	*2·7*	0·717	*1·8*	0·531	*1·3*	0·413	*1·0*	0·330	*0·8*	0·267	0·219	0·150
T_{25} =	*5·2*	0·970	*5·0*	0·619	*3·2*	0·437	*2·3*	0·323	*1·7*	0·246	*1·3*	0·191	0·149	0·093
T_{30} =	*5·2*	0·879	*4·5*	0·534	*2·8*	0·359	*1·9*	0·253	*1·3*	0·184	*1·0*	0·136	0·101	0·058
T_{35} =	*3·8*	0·796	*3·0*	0·460	*1·7*	0·295	*1·1*	0·199	*0·8*	0·138	*0·5*	0·097	0·069	0·036
T_{40} =	*5·2*	0·721	*3·7*	0·397	*2·1*	0·242	*1·3*	0·156	*0·8*	0·103	*0·5*	0·069	0·047	0·022
T_{45} =	*6·7*	0·653	*4·4*	0·342	*2·3*	0·199	*1·3*	0·122	*0·8*	0·077	*0·5*	0·049	0·032	0·014
X			*120·9*		*63·3*		*37·0*		*23·0*		*14·9*			
C =	*10·0*	1·59	*15·9*	1·29	*12·9*	1·16	*11·6*	1·10	*11·0*	1·06	*10·6*	1·03	1·02	1·01
e =	0·6	50·0	*30·0*	33·3	*20·0*	25·0	*15·0*	20·0	*12·0*	16·7	10·0	14·3	12·5	10·0
Z			*45·9*		*32·9*		*26·6*		*23·0*		*20·6*			
S = *X* − *Z*			*75·0*		*30·4*		*10·4*		*0·0*		*−5·7*			
R = *Se*× (*in shillings*)		·0·4	*30·0*	0·6	*18·2*	0·8	*8·3*	1·0	*0·0*	1·2	*−6·7*	1·4	1·6	2·0

to $$1{\cdot}04^{35}\left(\frac{1}{1{\cdot}04^{50}}+\frac{1}{1{\cdot}04^{100}}+\frac{1}{1{\cdot}04^{150}}+\ldots\ldots+\text{ad inf.}\right)$$

$$=\frac{1}{1{\cdot}04^{15}}+\frac{1}{1{\cdot}04^{65}}+\frac{1}{1{\cdot}04^{115}}+\ldots\ldots\text{ad inf.}$$

Now, if a rotation of 50 years were followed by a second similar rotation of 50 years and this by another and so on, for ever, then the sum of £2·5 would be received for the first thinning in each rotation, i.e. in the years 15, 65, 115, &c. The multiplier 0·646 is thus the factor for discounting the value of the 15-year thinning for a series of similar rotations to the zero year of the first rotation. In the sense in which it is employed on p. 152 it is the expectation value of all the first thinnings when discounted at 4 per cent. It may be objected that in arriving at equations I and II no account was taken of any rotation after the first, so that the intrusion of subsequent rotations at this point is unintelligible. Actually they become involved by returning the land as an asset at the end of the rotation and giving it the same value as at the beginning of the rotation; and though it would be unwise to plant larch repeatedly on land which previously carried pure larch we need not, for mathematical purposes, be afraid of basing our calculations on such a system.

In the same way each item of income and expenditure is multiplied by a factor which discounts that item, together with similar items in subsequent rotations, to the beginning of the first rotation. e is multiplied by $\frac{1}{\cdot 0p}$ which discounts an annuity of e per annum for ever.

The effect of changes in single items of income and expenditure on the financial yield can be readily observed in a completed schedule. Thus by wider spacing it would be possible to reduce the cost of planting by £1, but the value of the first thinning would be lost. Is this worth while? Referring to the 4 per cent. column a planting cost of £9 in place of £10 would reduce Z by 1·2. Losing the first thinning would reduce X by 1·6. Therefore a slightly lower rate of interest would be earned if this saving in the cost of planting were adopted. In a later section dealing with the importance of early thinnings it will be shown that where a good market exists for early thinnings these may far outweigh the influence of the final yield on the financial yield. This can be observed directly from the schedules, but would be difficult with the other methods of calculation. Other instances of the use of schedules will be referred to in chapters xiii–xv.

Schedules for rotations from 20 to 100 years are reproduced in Appendix III.

Financial yield: the indicator graph. The most favourable financial rotation can be calculated by determining the financial yield for various rotations and selecting that rotation which gives the highest financial yield. The indicator graph is a method of representing graphically the results of a series of calculations covering the rotations represented by a single money yield table, and though it does not directly give any results not otherwise obtained it is a useful pictorial method of presentation.

In Fig. 14 is reproduced the indicator graph for the money yield table for European larch quality II (with poor market for small sizes) in Table XXX (p. 127). For purposes of calculation the cost of planting has been taken as £10 and the annual cost of management as 12*s*. By means of the schedules the 'test' values of *S*, which are set out in Table XXXII, have been found.

TABLE XXXII. *Test values of* S *for European larch, Quality II (with poor market for thinnings).*

	Rotation in years.									
	25	*30*	*35*	*40*	*45*	*50*	*55*	*60*	*70*	*80*
Rate of	*Test values of S.*									
interest %	£	£	£	£	£	£	£	£	£	£
2	17·1	40·9	54·8	64·5	71·8	75·0	77·3	78·5	77·5	72·4
3	3·8	16·7	23·6	27·6	30·0	30·4	30·2	29·2	26·3	23·1
4	—2·6	5·1	8·8	10·5	11·1	10·4	9·5	8·3	5·4	2·2
5	—6·2	—1·1	0·8	1·2	1·2	0·0	—1·0	—2·0	—4·2	—6·4
6	—8·1	—5·0	—4·2	—4·2	—4·7	—5·7	—6·6	—7·5	—9·0	—10·3

In the indicator graph rotations are enumerated along the X axis and 'test' values of S along the Y axis. A curve for 2 per cent. is drawn through the points $x = 25, y = 17{\cdot}1$; $x = 30, y = 40{\cdot}9$; $x = 35$, $y = 54{\cdot}8$; . . . $x = 80$, $y = 72{\cdot}4$. In the same manner a curve for 3 per cent. is drawn through the points $x = 25$, $y = 3{\cdot}8$; $x = 30$, $y = 16{\cdot}7$, &c., and curves for 4 per cent. and 5 per cent. through their appropriate points. The curve for 6 per cent. is entirely below the $S = 0$ parallel, and consequently it has only theoretical significance. This method of graphing is a very exacting test of the consistency of a money yield table, and it will generally be found that the curves have to be somewhat smoothed.

It will be seen that the 2 per cent. curve reaches its maximum at about 60 years, the 3 per cent. curve at about 50 years, the 4 per cent. curve at about 45 years, and the 5 per cent. curve at between

40 and 45 years. If these maxima are joined up it will be found that they lie very nearly on a straight line (*AB*), and, though no mathe-

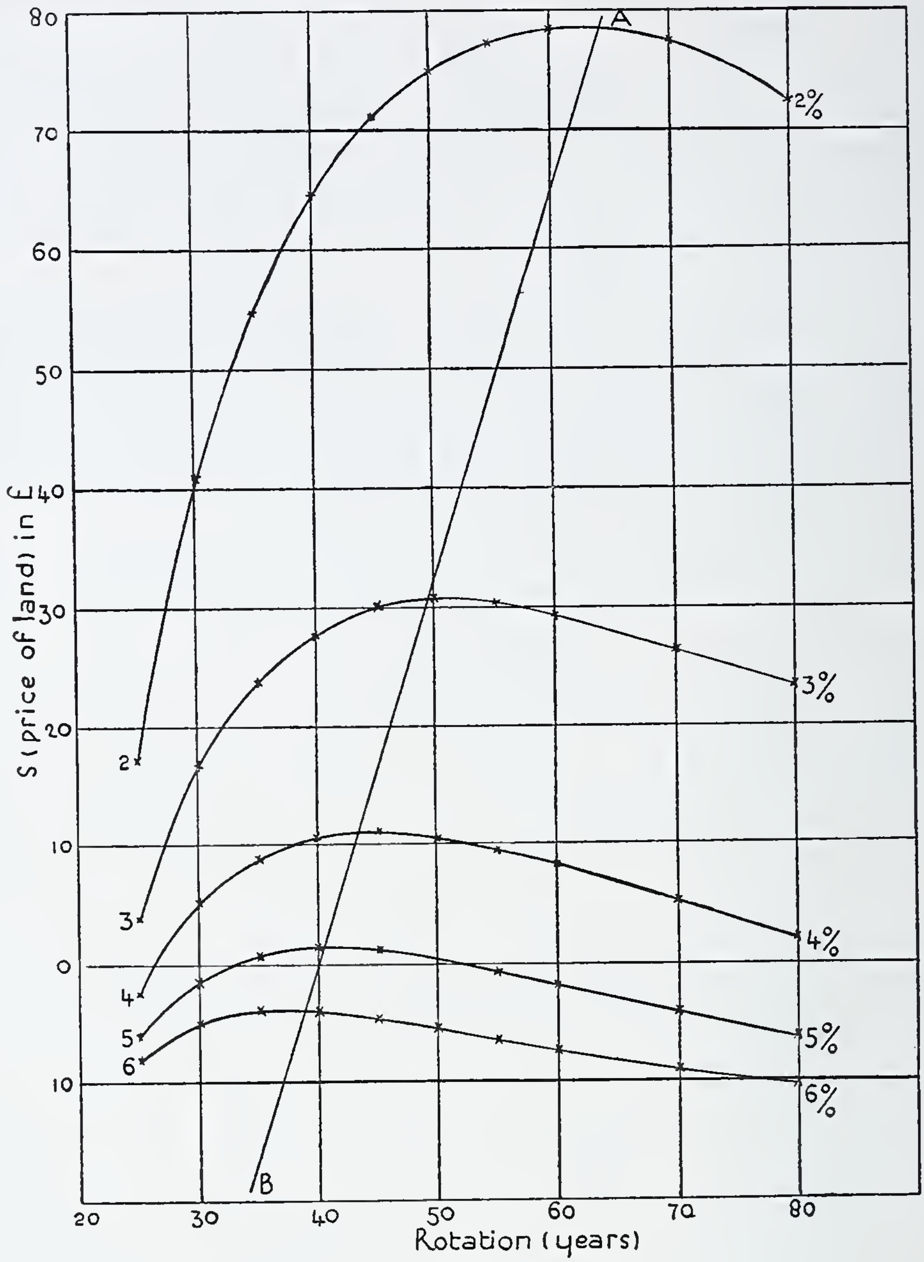

FIG. 14. Indicator Graph for European Larch, Quality II.
(Poor market for thinnings.)

matical proof that this should be so is as yet forthcoming, the straightness of this line appears to be a useful test of the consistency of the money yield table and the accuracy of working.

The financial yield for any rotation on land costing any known amount can be read with approximate accuracy directly from the indicator graph. Thus if land which yields a crop consistent with the money yield table costs £10 per acre the financial yield for various rotations are found by following along the horizontal, $S = 10$. The point where this strikes the upright line for rotation $= 25$ years lies between the 2 per cent. and 3 per cent. curves, and on a 25-year rotation the financial yield would be about 2·5 per cent. For a 30-year rotation it would be about 3·5 per cent., for a 45-year rotation about 4·1 per cent., and for an 80-year rotation about 3·6 per cent. The most favourable financial rotation is given by the point where the line $S = 10$ crosses the line AB. If the land costs £10 per acre the financial rotation is, therefore, 43 years; if, however, it costs £50 per acre the financial rotation is 55 years, and only 2·5 per cent. interest can be realized on the capital invested in the plantation.

Chapman's financial yield formula. If thinnings are valueless, as is not infrequently the case in remote forests with inferior extraction facilities, the financial yield formula may be rewritten.

$$S\,(1{\cdot}0p^r - 1) = Y_r - C\,.\,1{\cdot}0p^r - E\,(1{\cdot}0p^r - 1), \text{ where } E = \frac{e}{{\cdot}0p}.$$

From this, $$1{\cdot}0p^r = \frac{Y+S+E}{S+C+E},$$

from which equation p may be calculated by logarithms.[1] A difficulty, however, arises in the use of this formula since $E = \dfrac{e}{{\cdot}0p}$ and involves the unknown value p. Chapman overcomes this difficulty by putting $E = \dfrac{e}{{\cdot}0x}$, where x is as near an approximation to p as can be guessed, and from the above formula a value p', a nearer approximation to p, is calculated. He now puts $E = \dfrac{e}{{\cdot}0p'}$, and a further value p'' is calculated which is a still nearer approximation to the true value of p. 'The second solution of the equation will give a value for p usually within one-tenth of 1 per cent. of the true value.'

In a later volume[2] Chapman extended this method of approximations to include the returns from thinnings.

[1] H. H. Chapman, *Forest Valuation*, 1915. This formula has been used by Chaturvedi, *Indian Forester*, 1929, p. 16. [2] H. H. Chapman, *Forest Finance*, 1926, p. 144.

The uses and limitations of the financial yield method. The method of the financial yield is used more than any other method for obtaining the results given in this volume. The absolute rates as calculated by this method have about as little value as those calculated by other methods; timber prices and the purchasing power of money are too fluctuating to allow of accurate computations over a future period of 30 to 100 years. Such calculations are chiefly employed to estimate the comparative attractiveness of the use of various species under various methods of management. In British forestry the range of choice offered to the forester is generally very large, as nearly all forest growth is initiated by planting and planters are not confined to pre-existing species. The planter is also faced by a choice of various methods of planting, various planting distances, and various methods of thinning, &c., and it is in the making of decisions involved by these choices that financial calculations are helpful. It will generally be found that secular changes in timber prices and the purchasing power of money, which greatly affect the actual financial yield obtained, do not greatly influence the relative attractiveness of two different systems. For instance, if Corsican pine is a more profitable tree to plant than Scots pine with present prices, it will also be the more profitable tree if all prices are doubled (see p. 193).

It is always necessary to use common sense in interpreting the results of forest finance calculations. Paradoxes frequently arise, and this is especially the case with computations dealing with those forms of forest management which yield very low rates of interest.

X

METHODS OF ESTIMATING PROFITABLENESS IN FORESTRY (*contd.*)

The Nilambur teak plantations: have earned a financial yield of 6·9 per cent. The irrigated plantations of Changa Manga. Methods using compound interest, the rate of interest being fixed: soil expectation value. The soil expectation value formula. The forest per cent. The calculation of profit. Method of estimating the cost of production of timber. The indicating per cent. or current annual forest per cent.: indicating per cent. at various ages for European larch, Quality II. Comparison with financial yield. The forest rental: method not involving interest on capital: rotation of highest income has no economic attractiveness.

The Nilambur teak plantations. The publication of costs and expenditure for these plantations from 1840 to 1917 offers an almost unique opportunity for estimating the profitableness of a completed large-scale operation. A large extent of forest in the Nilambur district was gradually acquired by purchase and lease by the Government of Madras, and an extensive series of teak plantations was initiated in 1840. The annual profit or loss, capital expenditure being included with costs of management, has been recorded.[1] During the early years of operation, until 1879, there was nearly always a loss on the year's working which was due to making plantations and the occasional purchase of new land. Each year, however, there was some income from the sale of timber and firewood, and in later years the proceeds from thinnings were more than sufficient to pay for the annual cost of maintenance. In 1917/18 maincrop felling operations were started, and the working plan allowed of regular subsequent fellings which, it was estimated, would yield an annual net profit of Rs. 3,25,000.[2]

From this series of figures it is possible to calculate the rate of compound interest which has been earned on the money invested in the plantations, i.e. the financial yield of the transaction. It must be remembered that the financial yield is determined by bringing forward all expenditure at various rates of interest to a given year and comparing these totals with the totals of all income brought forward at the same rates of interest to the same year, plus all outstanding assets. The rate of interest at which these two amounts are found

[1] R. Bourne, *Nilambur Valley Working Plan*, Madras, Government Press, 1921, vol. i, p. 73.

[2] In the year 1919/20 the management of these forests was interrupted by the Moplah rebellion.

TABLE XXXIII. *Net gain or loss for each year from* 1840/41 *to* 1917/18 *on the Nilambur teak plantations, and figures carried forward with compound interest to* 1918/19.

Figures in hundreds of rupees.

	Actual.		With compound interest.					
			5%		6%		7%	
Year.	*Net loss.*	*Net gain.*	*Loss.*	*Gain.*	*Loss.*	*Gain.*	*Loss.*	*Gain.*
1840–1	84	—	3,746	—	7,900	—	16,200	—
1	28	—	1,192	—	2,490	—	5,020	—
2	13	—	528	—	1,086	—	2,210	—
3	21	—	815	—	1,662	—	3,360	—
4	23	—	847	—	1,702	—	3,450	—
5	29	—	1,015	—	2,030	—	4,090	—
6	31	—	1,032	—	2,045	—	4,100	—
7	32	—	1,017	—	1,985	—	3,935	—
8	25	—	761	—	1,477	—	2,850	—
9	28	—	808	—	1,540	—	2,982	—
1850–1	30	—	822	—	1,560	—	3,000	—
1	20	—	520	—	981	—	1,848	—
2	—	2	—	50	—	92	—	174
3	25	—	595	—	1,102	—	2,033	—
4	28	—	633	—	1,160	—	2,128	—
5	26	—	559	—	1,015	—	1,846	—
6	29	—	595	—	1,065	—	1,910	—
7	21	—	410	—	725	—	1,302	—
8	6	—	112	—	198	—	348	—
9	—	18	—	317	—	558	—	973
1860–1	—	17	—	286	—	493	—	850
1	30	—	480	—	825	—	1,410	—
2	—	109	—	1,657	—	2,835	—	4,800
3	52	—	759	—	1,282	—	2,148	—
4	—	108	—	1,490	—	2,485	—	4,160
5	18	—	237	—	396	—	648	—
6	—	131	—	1,637	—	2,660	—	4,460
7	114	—	1,368	—	2,175	—	3,650	—
8	11	—	126	—	203	—	324	—
9	65	—	709	—	1,130	—	1,790	—
1870–1	50	—	520	—	820	—	1,290	—
1	174	—	1,723	—	2,690	—	4,187	—
2	898	—	8,440	—	13,100	—	20,125	—
3	94	—	844	—	1,294	—	1,973	—
4	122	—	1,044	—	1,585	—	2,395	—
5	75	—	607	—	920	—	1,374	—
6	—	60	—	466	—	694	—	1,028
7	7	—	52	—	76	—	112	—

Figures in hundreds of rupees.

With compound interest.

Year.	*Actual.* *Net loss.*	*Net gain.*	5% *Loss.*	*Gain.*	6% *Loss.*	*Gain.*	7% *Loss.*	*Gain.*
1868	—	84	—	592	—	864	—	1,257
9	63	—	422	—	610	—	882	—
1880–1	—	381	—	2,460	—	3,490	—	4,985
1	—	174	—	1,057	—	1,504	—	2,127
2	—	46	—	266	—	375	—	525
3	—	263	—	1,450	—	2,023	—	2,810
4	300	—	1,575	—	2,175	—	2,993	—
5	—	362	—	1,810	—	2,478	—	3,380
6	243	—	1,156	—	1,568	—	2,117	—
7	—	41	—	186	—	249	—	334
8	501	—	2,163	—	2,870	—	3,810	—
9	5	—	21	—	27	—	36	—
1890–1	—	20	—	78	—	102	—	133
1	35	—	131	—	169	—	217	—
2	53	—	188	—	241	—	308	—
3	—	290	—	983	—	1,247	—	1,575
4	—	104	—	335	—	422	—	528
5	41	—	126	—	157	—	194	—
6	—	228	—	666	—	821	—	1,010
7	—	433	—	1,206	—	1,472	—	1,793
8	—	88	—	233	—	282	—	341
9	—	177	—	448	—	536	—	641
1900–1	—	1,170	—	2,818	—	3,340	—	3,960
1	—	309	—	708	—	833	—	977
2	—	64	—	139	—	163	—	189
3	—	31	—	64	—	74	—	86
4	—	30	—	59	—	68	—	77
5	16	—	30	—	34	—	39	—
6	—	895	—	1,607	—	1,798	—	2,015
7	—	351	—	600	—	666	—	739
8	—	713	—	1,162	—	1,275	—	1,402
9	—	866	—	1,342	—	1,463	—	1,592
1910–1	—	306	—	452	—	488	—	526
1	—	424	—	597	—	636	—	681
2	—	658	—	881	—	933	—	988
3	—	262	—	335	—	351	—	368
4	—	566	—	688	—	714	—	742
5	—	778	—	901	—	925	—	953
6	—	856	—	944	—	962	—	981
7–8	—	3,203	—	3,360	—	3,395	—	3,430
Total			38,728	34,330	66,070	43,766	114,634	57,590
Total Loss			+4,398		+22,304		+57,044	

to be equal is the financial yield. In this case it is simpler to bring forward the net losses or net gains for each year and to find the rate of interest at which the present value of net losses minus net gains (i.e. the total net loss with compound interest) is equal to the present value of assets.

In Table XXXIII are shown the net loss or net gain for each year from 1840/41 to 1917/18 and the value of each item when brought forward to the year 1918/19 with compound interest at 5, 6, and 7 per cent. It is found that the total loss in 1918/19 when calculations are made with 5 per cent. interest is Rs. 4,39,800, at 6 per cent. Rs. 22,30,400, and at 7 per cent. Rs. 57,04,400.

By the year 1918/19 a more or less normal forest had been built up from which it was estimated that an annual net profit of Rs. 3,25,000 might be drawn in 1918/19 and subsequent years. The value of this asset must be capitalized at the same rates of interest as were used in bringing forward past losses, i.e. 5, 6, and 7 per cent. At 5 per cent. the capitalized value (to 1918/19) of an annual income beginning in 1918/19 of Rs. 3,25,000 is

$$3{,}25{,}000\left(1+\frac{1}{0\cdot05}\right)$$

which is Rs. 68,25,000. At 6 per cent. it is Rs. 57,41,700, and at 7 per cent. Rs. 49,67,900.

Therefore the net gain of the whole enterprise is

at 5 per cent.	68,25,000 − 4,39,800	=	63,85,200
„ 6 „	57,41,700 − 22,30,400	=	35,11,300
„ 7 „	49,67,900 − 57,04,400	=	−7,36,500.

By graphing these figures it will be found that at 6·9 per cent. the net gain of the whole enterprise is approximately nil. In other words the financial yield of the enterprise is 6·9 per cent., i.e. the money invested in the forests has yielded interest at the rate of 6·9 per cent. Figures are not available for ascertaining the extent to which a rise in prices generally, and in teak prices in particular, have contributed to this result. The year 1917/18, when the future income was assessed, was a time of high prices, and prices have since fallen, but there is reason to expect a further advance in teak prices in the future which is not allowed for in the assessment of future returns.

The irrigated plantations of Changa Manga.[1] Another example is

[1] R. S. Troup, *The Silviculture of Indian Trees*, vol. i, pp. 306–11, Oxford, 1921.

afforded by the irrigated plantations of Changa Manga in the Lahore district of the Punjab. These plantations were initiated in 1866, when 780 acres were taken over, but large extensions were made subsequently and by 1926 over 9,000 acres had been planted or sown. The predominant species are sissoo (*Dalbergia sissoo*) and the mulberry (*Morus alba*).

Calculations at 4 per cent. compound interest show that by 1913/14 the whole of the capital had been paid off by income from the plantations and that a profit of Rs. 17,710 remained over in addition to the capital asset represented by the existing plantations. The following quotation[1] provides an example of an alternative method of calculation which employs the conception of the *financial yield*.

'An independent calculation made with the view of ascertaining the rate of interest yielded by the plantation by the end of 1913/14 determined the rate of interest to be 4·67 per cent. The method employed was to ascertain at what rate of interest (*a*) and (*b*) are equal, where (*a*) represents the value at the outset of the annual profits and of the present estimated value of the property less the value at the outset of the annual losses, and (*b*) represents the value at the outset of the original value of the property and of all capital expenditure incurred. In round figures the values with interest at 4·67 per cent. are as follows:

		Rs.
(*a*)	Value at outset of annual profits and of present estimated value of property	4,18,200
	Value at outset of annual losses	31,200
	Difference . . .	3,87,000
(*b*)	Value at outset of original value of property and of capital expenditure.	3,87,000

'This calculation probably errs on the side of safety: not only was the present value of the land overstated, but no revenue was allowed for until the first fellings commenced in 1881/82, although the receipts up to that year exceeded Rs. 1,00,000 from grass, grazing, cotton cultivation, and other items.'

Methods using compound interest, the rate of interest being fixed. Most of the continental calculations dealing with the profitableness of forestry have been made with a fixed arbitrary rate of interest called 'the forest per cent.' The principle of this method is that, if all items of income and expenditure (other than the cost of

[1] Ibid., p. 311.

the land) are discounted at the forest per cent. to the beginning of the rotation, the amount by which discounted income exceeds discounted expenditure represents the upper limit of the sum which may profitably be paid for the land. Thus if all anticipated income and all anticipated expenditure (other than land cost), when discounted to the beginning of the rotation at 6 per cent. interest, leave a balance of £5 in favour of the former, then £5 is the most that can be paid for the land so as to yield 6 per cent. on the whole investment. This is expressed by saying that the *expectation value* of the land is £5 if calculations are made at 6 per cent.

Alternatively, since 6 per cent. on £5 is 6*s.* per annum, the plantation may be said to earn a rent of 6*s.* per acre per annum on the land which it occupies. For this reason such calculations are frequently termed 'rentability' calculations, and in choosing between different methods of management it is financially sound to choose that method which yields the highest rent on the land.

It is clear that this method involves exactly the same figures as the method of the financial yield. The difference lies in the fact that in this method the land value is regarded as the unknown, whereas in the financial yield method the rate of interest is the unknown which has to be found by solution. The same equation does for both, though it is arrived at by different routes.

The soil expectation value[1] formula. Using the same symbols as before and using S_e for the desired expectation value of the land, then, if conditions remain constant for an indefinite period, and if at the end of each rotation the same species is planted and managed in the same manner as in the previous rotation, the income from final yields and thinnings will be:

Y_r in the year	r,	and again in the years			$2r, 3r, 4r, \ldots$		indefinitely.
T_a ”	”	a,	”	”	”	$r+a, 2r+a, 3r+a,$	”
T_b ”	”	b,	”	”	”	$r+b, 2r+b, 3r+b,$	”
T_q ”	”	q,	”	”	”	$r+q, 2r+q, 3r+q,$	”

If all these returns are discounted to the year 0, their value is:

$$Y_r\left(\frac{1}{1\cdot 0p^r}+\frac{1}{1\cdot 0p^{2r}}+\frac{1}{1\cdot 0p^{3r}}+\ldots\ldots\ldots ad\ infin.\right)$$

[1] 'Land Expectation value' is a much better term since the productivity of a site depends on altitude, aspect, climate, &c., as well as soil. Unfortunately 'soil expectation value', a literal translation of the German *Bodenerwartungswert*, has become fixed by use throughout the text-books.

$$+T_a\left(\frac{1}{1\cdot 0p^a}+\frac{1}{1\cdot 0p^{r+a}}+\frac{1}{1\cdot 0p^{2r+a}}+\quad\dots\ ad\ infin.\right)$$

$$+T_b\left(\frac{1}{1\cdot 0p^b}+\frac{1}{1\cdot 0p^{r+b}}+\frac{1}{1\cdot 0p^{2r+b}}+\quad\dots\quad ,,\quad\right)$$

$$+\dots+T_q\left(\frac{1}{1\cdot 0p^q}+\frac{1}{1\cdot 0p^{r+q}}+\frac{1}{1\cdot 0p^{2r+q}}+\dots\quad ,,\quad\right)$$

$$=Y_r\frac{1}{1\cdot 0p^r-1}+T_a\frac{1\cdot 0p^{r-a}}{1\cdot 0p^r-1}+T_b\frac{1\cdot 0p^{r-b}}{1\cdot 0p^r-1}+\dots+T_q\frac{1\cdot 0p^{r-q}}{1\cdot 0p^r-1}\ ^{1}$$

$$=\frac{Y_r+\Sigma T_a\,.\,1\cdot 0p^{r-a}}{1\cdot 0p^r-1}.$$

The costs are C in the years 0, r, $2r$, &c., $+e$ in every year in perpetuity. Therefore the discounted value of the costs is

$$C\frac{1\cdot 0p^r}{1\cdot 0p^r-1}+\frac{e}{1\cdot 0p-1}.$$

The expectation value of the soil is the difference between these two amounts. Therefore

$$S_e=\frac{Y_r+\Sigma T_a\,.\,1\cdot 0p^{r-a}-C\,.\,1\cdot 0p^r}{1\cdot 0p^r-1}-\frac{e}{\cdot 0p}\quad\dots\dots\quad \text{III.}$$

This equation is generally called the Faustmann Formula and has been in use for many decades.

For determining soil expectation values the schedules explained on p. 138 may be used; in fact, the test values for the land which are calculated by means of the schedules are nothing more than soil expectation values, and Table XXXII (p. 143) is really a table of soil expectation values. It will be seen from the table that, with a fixed money yield table, the expectation value of the soil varies, not only with the rotation, but with the rate of interest with which the calculation is made. The higher the rate of interest the lower will be the expectation value; in other words, if more money is paid in interest less can be paid for the land.

The forest per cent. The forest per cent. is the rate of interest used in estimating soil expectation values and in other similar calculations.

[1] If x is less than 1 then the series $1+x+x^2+\dots ad\ inf.=\frac{1}{1-x}$. Therefore the series $x+x^2+x^3+\dots ad\ inf.=\frac{1}{1-x}-1=\frac{x}{1-x}$. The summation of each of the above series follows readily from this.

If these calculations are to have any real significance the forest per cent. should be the rate of interest at which money can be borrowed on moderately good security, at present about 6 per cent. for private individuals or companies and $4\frac{1}{2}$ to 5 per cent. for governments. Under favourable conditions in Britain forestry may return these rates of interest, but on the continent, where growth is slower and fast growing exotics are not yet in favour, it is unusual for forests to yield more than 3 per cent. interest. Under such conditions, if calculations are carried out with 5 or 6 per cent. compound interest, all soil expectation values are negative, and the results, in addition to being very disheartening, are difficult to interpret.

Many arguments have been advanced in favour of adopting a lower rate of interest than the national rate for forest calculations. The most important of these is that in settled countries considerable kudos attaches to land-ownership, and many people are prepared to pay for a landed estate a higher price than is justified by the income from the investment. It does not appear in Britain, however, that the average landowner is prepared to invest an additional sum at a low rate of interest in order to have well-managed woods.

For forestry to prove attractive from a purely business point of view the rate of interest to be secured would need to be higher than that which can be obtained by investing in sound industrial undertakings. For, as an investment, forestry has the two great drawbacks, that returns are very long delayed and that the capital is difficult to realize if necessity arises. From the general investor's point of view these drawbacks more than compensate for the probability that timber prices will rise. Except on very large estates where the risk is well spread, the security of the investment is endangered by fire, gales, insect and fungus diseases, and though the first of these risks may be covered by insurance, the others cannot be avoided, though they may be moderated by sound silvicultural practice.

An additional argument which is sometimes used for a low forest per cent. is that, owing to the progressive destruction of the virgin forests of the world, good forest management is becoming a public necessity. Forestry provides one of the most important raw materials of industry, and human welfare would be very seriously affected if supplies of timber and pulp wood were to fail. It is therefore the duty of states to undertake the management of forests even if, in so doing, they receive a lower rate of interest on their investment than they have to pay on loans which they raise for the purpose. If a government borrows at 5 per cent. it might regard 2 per cent. of this as payment for the public good which forestry brings, and it

should then demand only 3 per cent. in direct financial return from the forest.

The contention that governments may be justified in maintaining the timber-supply of their countries, even if it involves a financial loss, is in accordance with thoroughly sound principles of government. It is desirable, however, that governments should carry out this function at the least possible expense to the public and, for this purpose, calculations of financial yields are more useful than calculations of soil expectation values. The former show the highest rate of interest which can be obtained, whereas the latter show how forests could best be managed if money could be borrowed at the forest per cent.; and, if the forest per cent. is below the rate at which money can actually be borrowed, this assumption invalidates results. That the difference in method may have a considerable influence on practical decisions is shown by the example on p. 210, in which the financial rotation for oak is shown to be about 30 years longer if calculations are made at 3 per cent. than if the highest financial yield is aimed at.

The low rate of interest with which calculations have generally been made greatly detracts from the usefulness of soil expectation value calculations, and though practical examples of the use of this method are given on pp. 213 ff., its general application is not recommended.

The calculation of profit. If the sale price of an article is greater than the cost of production, including an appropriate share of the overhead charges, then the manufacturer makes a profit on the production of the article. The cost of production of an article, however, is rather a vague term, and there is no generally accepted method of computing it; it is clear that it must include an allowance for the wear and tear of the machinery and buildings and a share of rates and taxes, but it is uncertain whether it must cover interest on borrowed capital. If a producing company has to pay interest on bank debts, debentures, preference shares, and ordinary shares then it appears just that the interest on the first two should be included in costs of production, but it is doubtful whether interest on preference shares should be included, and it is generally accepted that the dividends on ordinary shares are paid out of profits and are not so included.

It has already been shown (p. 134) that, if no charge is made for interest on capital, the cost of growing timber is nearly always much less than the sale price; but, if interest on capital, even at a very moderate rate of interest, is included this item generally amounts to

very much more than all other costs put together, and the rate at which interest is charged has a profound influence on the total cost.

If all the money required for financing a plantation is borrowed at a fixed rate of compound interest so that a debt against the planter is gradually built up, and if at the end of the rotation the final crop and land are sold, then the planter will find that he has either earned a profit or suffered a loss. If he has borrowed at a lower rate than the financial yield actually obtained he will have earned a profit, if he has borrowed at a higher rate he will have suffered a loss. It is thus apparent that the question of profit is dependent on the rate of interest at which the planter can borrow money. If he has used his own money a profit may be said to have been earned if the financial yield realized exceeds what he considers to be a satisfactory rate of interest on his investment. As, however, this is psychologically improbable, the conception of profit is seldom applied to forestry unless the capital has been borrowed.

If land is bought for S per acre and money is borrowed from a bank at the rate of interest p, and if all costs, including interest, are paid for out of a bank overdraft which is reduced periodically by paying the bank all receipts, then the overdraft at the end of the rotation will be

$$S \cdot 1{\cdot}0p^r + C \cdot 1{\cdot}0p^r + e \cdot \frac{1{\cdot}0p^r - 1}{{\cdot}0p} - (Y_r + \Sigma T_a \cdot 1{\cdot}0p^{r-a} + S).$$

If there is a profit the above value will be negative and the profit will be

$$Y_r + \Sigma T_a \cdot 1{\cdot}0p^{r-a} - C \cdot 1{\cdot}0p^r - e \cdot \frac{1{\cdot}0p^r - 1}{{\cdot}0p} - S(1{\cdot}0p^r - 1).$$

If S_e is the expectation value of the soil for the conditions under consideration at the rate of interest p (equation III, p. 153), then the above amount is equal to

$$P = (1{\cdot}0p^r - 1)(S_e - S) \ldots\ldots\ldots\ldots\ldots \text{IV.}$$

From this it is clear that there is only a profit if the expectation value is greater than the cost value of the land, i.e. if the financial yield of the plantation is greater than the rate of interest at which money can be borrowed. This is self-evident.[1]

[1] If the plantation is managed by a series of similar rotations yielding similar financial results in perpetuity, then the profit P (of equation IV) is earned in each of the years r, $2r$, $3r$, &c. If all these profits are discounted, at rate of interest p, to the year 0, the discounted value is $\dfrac{P}{1{\cdot}0p^r - 1} = S_e - S$, a formula familiar to text-books.

Calculations to show the actual or estimated profit or loss at the end of a rotation are theoretically attractive. The method, however, suffers from drawbacks which make it of comparatively little value in practice. In the first place, it is seldom that money is borrowed for planting at a fixed rate of interest; and, in the second place, if the method is used to compare the comparative attractiveness of alternative courses, it is difficult to balance against each other different profits at different times. Thus one course may show an estimated profit of £20 per acre at the end of 40 years, another course a profit of £40 at the end of 60 years. Which is the more attractive? If, in order to compare such profits, they are all discounted to the beginning of the rotation, then the problem is reduced to finding that course which gives the highest expectation value of the soil, and, for reasons already stated, this method is inferior for several reasons to that of the financial yield.

Method of estimating the cost of production of timber. Profit might also be estimated in terms of the unit volume of timber. Thus, it might be shown that trees of Scots pine of a certain size cost so much *per cubic foot* to grow, some fixed rate of interest being allowed on capital. Owing to certain difficulties this method has not been used in the past. An attempt to overcome these difficulties has, however, been made, and as the work is new, and as the method has been adopted in connexion with an assessment of the costs of production of particular species in Britain, it has been thought better to devote a separate chapter to its consideration (see p. 176). In the meantime other traditional methods will be explained.

The indicating per cent.,[1] or current annual forest per cent. In previous sections a forest rotation has been treated as a whole. It is frequently desirable, however, to estimate the changes in value of a plantation that occur over various periods within the rotation. Thus, if a nearly mature wood is measured and valued and after the lapse of five years it is measured and valued again the owner can estimate the rate at which his capital is appreciating (due regard being paid to incidental costs and income) and whether it is better to allow the wood to continue to grow or to fell it and regenerate. This rate is called the *indicating per cent.* or *current annual forest per cent.*

The indicating per cent. is also used in experimental work for comparing the profitableness of different methods of thinning. Thus if two parts of a large twenty-year-old plantation are thinned in different ways it is possible by the use of indicating per cent.

[1] This useful term is Schlich's translation of Pressler's *Weiserprozent.*

formula to estimate the comparative profitableness of the two parts, taking into account the value of the thinnings and the value of the remaining stands and the costs of management.

The indicating per cent. formulae are based on the equation $p = \frac{I}{C} \times 100$. If a stand, m years old, has a value of Y_m per acre, which increases to the value of Y_{m+1} in the year $m+1$, then the net income for the year (including capital appreciation) is

$$I = Y_{m+1} - Y_m - e,$$

e being the cost of management for the year. The capital is represented by the land and the growing stock in the year m, to which it may be necessary to add something for buildings or other assets. In its simplest form this capital is $Y_m + S$. We therefore have the equation

$$p = \frac{Y_{m+1} - Y_m - e}{Y_m + S} \times 100 \ldots\ldots\ldots\ldots\ldots \text{V.}$$

It is not, however, possible to value woods accurately each year since the errors of measurement may be greater than the increment. Measurements have consequently to be made once in 5, 10, or more years. Thinnings may be removed in the interval and costs of management will be incurred annually. These amounts must be discounted or brought forward to a fixed year at compound interest, and the rate of interest should be the indicating per cent. it is desired to find. The indicating per cent. is then the rate of compound interest at which the capital appreciates over the period, and if we ignore thinnings and costs of management we could obtain it by solving the equation

$$(Y_m + S)\, 1{\cdot}0p^n = Y_{m+n} + S \ \ldots\ldots\ldots\ldots \text{VI.}$$

If, however, we take account of thinnings in the years a, b, c, and an annual cost of management e, we have the equation

$$(Y_m + S)\, 1{\cdot}0p^n + e\,(1{\cdot}0p^{n-1} + 1{\cdot}0p^{n-2} + \ldots + 1{\cdot}0p + 1)$$
$$= Y_{m+n} + S + \Sigma T_a \,.\, 1{\cdot}0p^{m+n-a}$$

$$\text{or } Y_{m+n} = Y_m \,.\, 1{\cdot}0p^n + S\,(1{\cdot}0p^n - 1) + e\,\frac{1{\cdot}0p^n - 1}{{\cdot}0p} - \Sigma T_a \,.\, 1{\cdot}0p^{m+n-a}$$
$$\ldots\ldots \text{VII.}$$

This equation can be solved in the same manner as the financial yield equation by trying various values of p and interpolating to find that value of p which makes the right hand side of the equation equal to Y_{m+n}.

The solving of the equation is simplified if we accept some arbitrary rate of interest [1] (the forest per cent.) at which to bring forward all but one of the items. Thus Kraft brings forward everything except Y_m at an arbitrary rate of interest q (generally about 3 per cent.), and the equation becomes

$$Y_{m+n} = Y_m \cdot 1{\cdot}0p^n + \left(S + \frac{e}{{\cdot}0q}\right)(1{\cdot}0q^n - 1) - \Sigma T_a \cdot 1{\cdot}0q^{m+n-a}$$

or
$$1{\cdot}0p^n = \frac{Y_{m+n} + \Sigma T_a \cdot 1{\cdot}0q^{m+n-a}}{Y_m} - \frac{S + \dfrac{e}{{\cdot}0q}}{Y_m}(1{\cdot}0q^n - 1).$$

This equation is directly soluble, but the result varies very much with the value of q chosen. This is taking illegitimate liberties with the idea of the indicating per cent., but Kraft's formula has been used for important calculations by Engler (p. 208).

In practice an approximately accurate value for the indicating per cent. can be obtained as follows. If the second measurement is taken when thinnings are made the value of the thinning can be added to the value of the main crop, i.e. it can be included in Y_{m+n}. If no other thinnings have been taken between the years m and $m+n$ the total gross income over the period, including capital appreciation, is the amount $Y_{m+n} - Y_m$.

The average annual gross income has therefore been $\dfrac{Y_{m+n} - Y_m}{n}$, and the average net income $\dfrac{Y_{m+n} - Y_m}{n} - e$.

The average value of the capital has been approximately

$$\frac{Y_m + Y_{m+n}}{2} + S.$$

The indicating per cent. is, therefore, approximately

$$p = \frac{\dfrac{Y_{m+n} - Y_m}{n} - e}{\dfrac{Y_m + Y_{m+n}}{2} + S} \times 100$$

$$= \frac{Y_{m+n} - Y_m - ne}{Y_m + Y_{m+n} + 2S} \times \frac{200}{n} \quad \ldots\ldots\ldots\ldots \text{VII.}$$

This value approximates most closely to the indicating per cent. at the year half-way between m and $m+n$, i.e. the year $m + \dfrac{n}{2}$.

[1] This Endres calls the *Wirtschaftszinsfuss*, the industrial rate of interest.

Equation VII may be conveniently applied to money yield tables, when n can be made equal to the interval between the thinnings. It is necessary to remember, however, that Y_{m+n} is the final yield for the year $m+n$, *including* the income from the thinning in that year, whereas Y_m is the final yield for the year m, *excluding* the income from thinning.

Applying equation VII to the money yield table for European larch, Quality II, with poor market for small thinnings (p. 127), and assuming that the value of the land is £10 per acre and the cost of management 12*s*. per annum we get the results given in Table XXXIV.

TABLE XXXIV. *Indicating per cent. and financial yield.*

Period.	*Middle year.*	*Indicating per cent.*	*Financial yield.* %
20–25	$22\frac{1}{2}$	$\frac{40{\cdot}7-14{\cdot}4-3{\cdot}0}{40{\cdot}7+14{\cdot}4+20}\times\frac{200}{5}=\frac{23{\cdot}3\times40}{74{\cdot}7}=12.5$	—
25–30	$27\frac{1}{2}$	$\frac{63{\cdot}4-35{\cdot}5-3{\cdot}0}{63{\cdot}4+35{\cdot}5+20}\times\frac{200}{5}=\frac{24{\cdot}9\times40}{120{\cdot}9}=8{\cdot}2$	3·0
30–35	$32\frac{1}{2}$	$\frac{85{\cdot}7-58{\cdot}2-3{\cdot}0}{85{\cdot}7+58{\cdot}2+20}\times\frac{200}{5}=\frac{24{\cdot}5\times40}{163{\cdot}9}=6{\cdot}0$	3·7
35–40	$37\frac{1}{2}$	$\frac{111-81{\cdot}9-3{\cdot}0}{111+81{\cdot}9+20}\times\frac{200}{5}=\frac{26{\cdot}1\times40}{212{\cdot}9}=4{\cdot}9$	4·0
40–45	$42\frac{1}{2}$	$\frac{137-106-3}{137+106+20}\times\frac{200}{5}=\frac{28\times40}{263}=4{\cdot}3$	4·1
45–50	$47\frac{1}{2}$	$\frac{160-130-3}{160+130+20}\times\frac{200}{5}=\frac{27\times40}{310}=3{\cdot}5$	4·1
50–55	$52\frac{1}{2}$	$\frac{183-152-3}{183+152+20}\times\frac{200}{5}=\frac{28\times40}{355}=3{\cdot}2$	4·0
55–60	$57\frac{1}{2}$	$\frac{205-174-3}{205+174+20}\times\frac{200}{5}=\frac{28\times40}{399}=2{\cdot}8$	3·9
60–65	$62\frac{1}{2}$	$\frac{227-195-3}{227+195+20}\times\frac{200}{5}=\frac{29\times40}{442}=2{\cdot}6$	3·9
65–70	$67\frac{1}{2}$	$\frac{249-217-3}{249+217+20}\times\frac{200}{5}=\frac{29\times40}{486}=2{\cdot}4$	3·8
70–75	$72\frac{1}{2}$	$\frac{266-237-3}{266+237+20}\times\frac{200}{5}=\frac{26\times40}{543}=1{\cdot}9$	3·7
75–80	$77\frac{1}{2}$	$\frac{281-255-3}{281+255+20}\times\frac{200}{5}=\frac{23\times40}{556}=1{\cdot}6$	3·7

Comparison of the indicating per cent., or current annual forest per cent., with the financial yield, or mean annual forest per cent. The indicating per cent. (or current annual forest per cent.) is the rate of interest which the annual increment in the value of a plantation represents on the utilization value of the growing stock and land. It takes no account of the cost of planting or any expenditure or income prior to the period considered.

The financial yield (or mean annual forest per cent.) is the rate of interest realized over a rotation on all money spent on the plantation and takes account of all items of expenditure and income during that rotation. The values of the financial yield in Table XXXIV are estimated from Fig. 14, p. 144.

These two rates of interest may be graphed for comparison as shown in Fig. 15. The continuous lines are smoothed curves through the points given by Table XXXIV. These lines are continued backwards towards the origin, following the direction indicated by general principles but without regard to detailed accuracy.

It will be seen from the graph that up to the year 43 the indicating per cent. is higher than the financial yield. This is due to the fact that the utilization value of a very young plantation is less than the cost value with compound interest on capital. At 20 to 25 years the utilization value is actually increasing by as much as 12 per cent. per annum, but the value is still so low that if cut the plantation will only yield 2·5 per cent. on the capital invested.

It is easy to see from general principles that as long as the indicating per cent. is higher than the financial yield the latter must be rising, for, since the plantation is earning more than the rate of interest so far earned on the whole rotation, the added earning in the year must raise the rate earned on the whole rotation. For the same reason, if the indicating per cent. is lower than the financial yield, the latter must be falling. It follows from this that the two curves cross at the maximum point of the financial yield, i.e. at the financial rotation. Comparison with the indicator graph on p. 144 shows that if S is £10 the financial rotation is 43 years.

The graph also shows that the indicating per cent. falls off far more rapidly than the financial yield. By continuing a rotation from 60 to 70 years the financial yield is only reduced from 3·9 to 3·8 per cent., but the indicating per cent., i.e. the rate of interest earned during that period, is only 2·5 per cent.

The forest rental: method not involving interest on capital. The expression forest rental is a misnomer which has unfortunately acquired a secure position in the terminology of forest economics.

The term stands for the annual net income per acre or per hectare which can be continuously drawn from an organized forest.

It is computed most simply for an ideally normal forest of r acres or hectares in which one acre or hectare is just planted, one is 1 year old, one 2 years old, and so on, the oldest area being $r-1$ years. At the time of felling each area is 1 year older.

From such a forest the annual income is derived from one unit area of final yield and one unit area thinned at each thinning period. The annual expenditure is the cost of planting one unit area and the annual maintenance of r units. The net income is therefore

$$Y_r + \Sigma T_a - C - re.$$

The net annual income per acre or per hectare is therefore

$$I = \frac{Y_r + \Sigma T_a - C - re}{r}.$$

As no forest is ideally normal the forest rental of a forest is in practice computed from statistics of volume, increment, and price, and is represented by the average net income which can be drawn from a forest without altering its capital value.[1] It is the object of most foresters to increase the capital value of their forests, and any increment in capital value may be added to the actual net income in order to arrive at the forest rental.

The forest rental is one of the quantities which will normally be derived from intensive book-keeping in the management of organized forests, and in this sense the principle of forest rental is innocuous. Unfortunately, however, it has become the contention of a large number of foresters that the economic objective of forest management should be so to organize forests that the highest possible forest rental is secured. This contention has particular bearing on the length of the rotation, and many foresters advocate the 'rotation of highest income', i.e. the rotation which yields the highest average income per unit area or the highest forest rental, regardless of the amount of capital that is necessary to produce this income.

The rotation of highest income is always very much longer than the rotation which yields the highest rate of interest on capital. In the example given in the next chapter the former rotation is 140 years and the latter 40 years. Consequently, the question of whether a forester is to aim at the highest forest rental or the highest financial

[1] In this discussion it is assumed that prices remain constant. If this is not the case it is difficult to estimate the forest rental in a forest of changing character; but it may be based on the assumption that the value of the growing stock should rise or fall in amount corresponding to changes in timber prices.

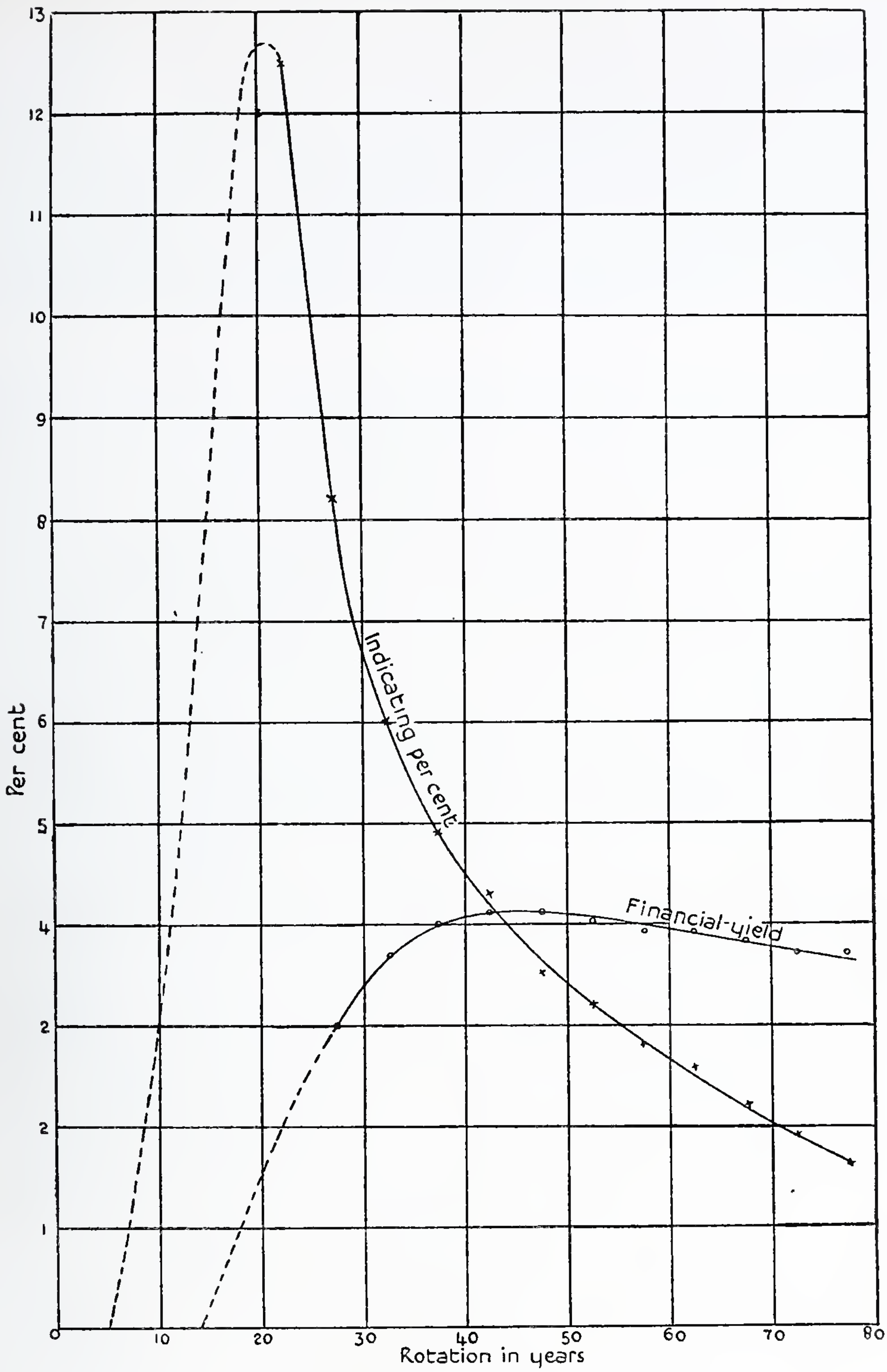

Fig. 15. Indicating per cent. and financial yield. (European larch, Quality II. Poor market for thinning.)

yield is a matter of great moment in forest management. The question has given rise to very bitter controversy, especially in Germany,[1] in which those whose chief interest is silviculture have defended the rotation of highest income against forest economists. There may be many reasons for extending the rotation beyond the strictly financial rotation, but a careful analysis shows that the rotation of highest income has no special attractiveness from an economic point of view and cannot, therefore, be defended on any economic ground. An analysis which demonstrates this is given in the next chapter.

[1] For discussion on the recent literature of this subject see Hiley, *Forestry*, vol. i, No. 1, p. 197, Oxford, 1927.

XI

FINANCIAL ANALYSIS OF A MONEY YIELD TABLE

Schwappach's money yield table for Scots pine. Quantities to be calculated. (1) The financial yield. (2) The net annual income from a normal forest. (3) The capital value of a normal forest: realization value for financially mature forest; difficulty of valuing immature stands: cost value: expectation value. (4) Net income expressed as a rate of interest on capital value. The principle of diminishing returns applied to the length of the rotation.

Schwappach's money yield for Scots pine. The complex relationship between the length of rotation in forestry and the profitableness of the undertaking can best be studied by a detailed analysis of the deductions which can be drawn from a money yield table. The length of the rotation that should be adopted in particular cases is generally discussed from the silvicultural and political points of view as well as the financial and, though it is necessary to pay regard to silvicultural and political considerations, the discussion is bound to be confused unless each of these considerations is first analysed separately. In the present chapter attention will be paid to the financial view only and, in order that criticism on other grounds may be avoided, a classical money yield table will be used which has very little relation to present prices or returns. The discussion can thus be kept on an academic level, and the principles of the subject more clearly enunciated.

The money yield table chosen for this analysis is Schwappach's table for Scots pine, Quality II (of 5 qualities) published in 1908.[1] This table is based on a large number of measurements and price observations in Prussia and, as Schwappach's deductions are very different from the present writer's, it cannot be suggested that the table is unfairly constructed to show any particular conclusions. In this table allowance has been made for the difference between the actual volumes obtained in forest practice and the ideal yields of the yield table but, as no deduction has been made for loss by rot, insects, or fire it has been thought advisable to reduce the money values given in this table for 'remaining stands' by 25 per cent., so that there may be no question of over-valuing the yields. Certain irregularities have been smoothed and the yields, both of remaining stands and thinnings, have been rounded off to the nearest 50 marks in order to simplify calculations.

[1] Dr. A. Schwappach, *Die Kiefer*, Neudamm, 1908, p. 146.

TABLE XXXV. *Schwappach's money yield table for Scots pine, Quality II, with remaining stands reduced by 25 per cent., and values rounded off.*

Age. Years.	*Remaining stand. Marks per ha.* Z_r	*Thinnings. Marks per ha.* T_a	*Final yield. Marks per ha.* Y_r
10	40	—	40
20	200	—	200
30	700	100	800
40	1,150	250	1,400
50	1,550	300	1,850
60	1,950	350	2,300
70	2,300	350	2,650
80	2,700	400	3,100
90	3,150	450	3,600
100	3,600	450	4,050
110	4,000	500	4,500
120	4,450	500	4,950
130	4,800	500	5,300
140	5,000	500	5,500

It is assumed in the calculations that plantations are clear-felled when mature and planted the same winter at a cost of 80 mks. per ha., and that the annual cost of management is 6 marks per ha.; both these figures are Schwappach's estimates. It is further assumed that the sale value of the land is 100 mks. per ha. Thus $C = 80$, $e = 6$, $S = 100$.

On the basis of these figures various calculations can be made of which the most useful are the following:

(1) The *financial yield* on various rotations.
(2) The *net annual income from a normal forest* worked on various rotations and reduced to the average income per hectare.
(3) The *capital value of a normal forest* worked on various rotations and reduced to the average value per hectare.
(4) The *net income expressed as a rate of interest on the capital value.*

(1) **The financial yield.** This is worked out in the manner explained in chapter ix, and an indicator graph is given in Fig. 16. In Table XXXVII (p. 173), col. 2, the financial yields, calculated to the nearest 0·05 per cent., are shown corresponding to a land value of 100 marks per ha. It will be seen that the financial rotation is 40 years [1] and that the financial yield at that rotation is 4·45 per cent.

[1] This means that the highest financial yield is obtained on a pit-wood rotation. See, however, p. 221.

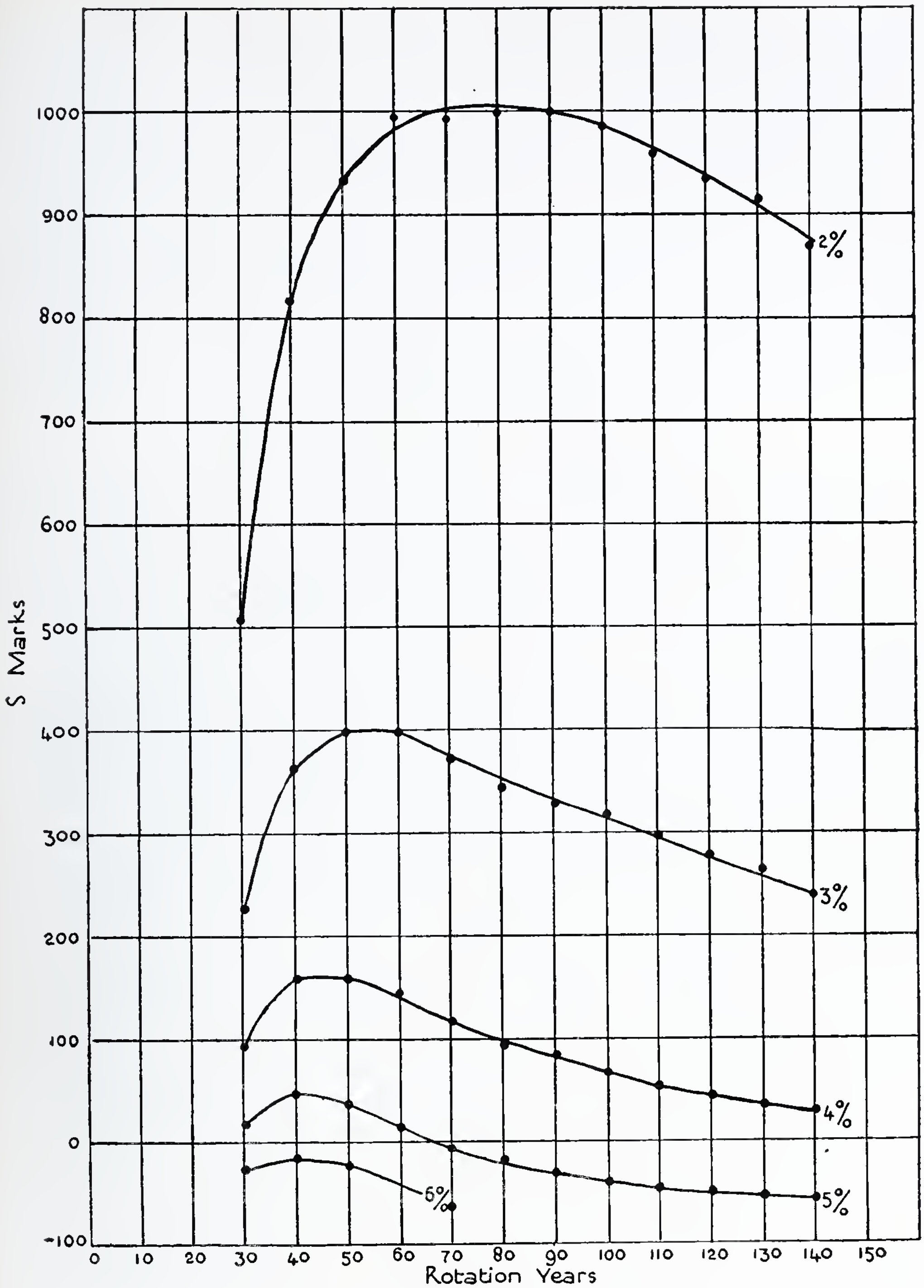

Fig. 16. Indicator graph for Scots pine, Quality II.
(Schwappach's money yield table.)

(2) **The net annual income from a normal forest.** The income from a single plantation is discontinuous and culminates in a very large amount when the plantation is felled. Thus no figure can be estimated as the annual income from a single plantation. It is very easy, however, to estimate the annual income from an ideally normal forest in which an equal area is cut each year yielding an equal net profit, and in which the costs remain constant from year to year. The income from a given area will be greatly influenced by the length of the rotation adopted on the area, and in order to compare these incomes it is necessary to reduce the income to the average income per hectare.

As shown on p. 162 the net income per hectare is

$$(Y_r + T_a + T_b + \ldots\ldots + T_q - C - re)/r.$$

Applying this calculation to the money yield table, incomes have been computed for each rotation from 30 to 140 years, and these incomes are tabulated in Table XXXVII, column 5. The income becomes greater as the rotation becomes longer and appears to culminate at about 140 years. This is therefore the *rotation of highest income.*

(3) **The capital value of a normal forest.** The next step is to estimate the various capitals on which these incomes are earned, i.e. the average capital value per hectare of ideally normal forests worked on various rotations. Various methods are set out in the text-books of forest valuation for computing the capital value of a forest, but none of these is entirely satisfactory. Most of them involve compound interest at some arbitrary rate, and the calculated value can be made anything the writer likes by taking a suitable rate of interest. What is required is the price which the forest would fetch in an open competitive market, and this will be determined, in the first place, by the realizable value of the growing stock and the value of the land. When the timber is ripe for felling then its standing value is the basis for valuation, and as, in the present case, the plantations are financially mature at 40 years all stands of 40 years or over can be valued at the price they would fetch for felling. When they are less than 40 years old, however, it is financially profitable to let them grow on, i.e. *their expectation value is greater than their utilization value.* Thus the utilization value of a 5-year-old plantation is probably nil; but money has been invested in producing it and it clearly has a value to the forester.

The text-books of forest valuation present two methods of calculating the value of an immature plantation; one gives the *cost value,*

the other the *expectation value.* The cost value is obtained by bringing forward all costs at some rate of compound interest and deducting from the total the value of all income brought forward in the same manner. The expectation value is obtained by discounting all future returns at some rate of interest and deducting the discounted value of all future costs.

Applying these two methods to the problem of valuing a hectare of pine plantation 20 years old and adopting the money yield table costs and returns we obtain values in the following way:

(*a*) Cost value. The costs of producing such a plantation are the price of the land and planting, 20 years previously, and the annual expenditure each year. This amounts to

$$(S+C)\,1{\cdot}0p^{20}+e\,(1+1{\cdot}0p+\ldots+1{\cdot}0p^{19})$$

or

$$(S+C)\,1{\cdot}0p^{20}+e\,.\frac{1{\cdot}0p^{20}-1}{{\cdot}0p}$$

$$=(100+80)\,1{\cdot}0p^{20}+6\frac{1{\cdot}0p^{20}-1}{{\cdot}0p}.$$

(*b*) Expectation value. The highest financial yield will be obtained by felling the plantation when it is 40 years old. The land will also then be available for sale or replanting. In addition a thinning worth 100 marks will be obtained in the year 30, and 6 marks must be spent per annum on maintenance. The value is therefore:

$$(Y_{40}+S)\frac{1}{1{\cdot}0p^{20}}+T_{30}\frac{1}{1{\cdot}0p^{10}}-e\left(\frac{1}{1{\cdot}0p}+\frac{1}{1{\cdot}0p^{2}}+\ldots+\frac{1}{1{\cdot}0p^{20}}\right)$$

$$=(1400+100)\frac{1}{1{\cdot}0p^{20}}+100\frac{1}{1{\cdot}0p^{10}}-6\frac{1{\cdot}0p^{20}-1}{{\cdot}0p\times1{\cdot}0p^{20}}.$$

Both these values will be greatly affected by the value chosen for p, the rate of interest, and a high value of p will increase the cost value but diminish the expectation value.

Table XXXVI gives the figures calculated for cost and expectation values when the rate of interest is 3, 4, 4½, and 5 per cent. respectively. It will be seen from this table that the two values are nearest to each other when the calculation is made with 4½ per cent. interest, and they will be equal if the rate of interest is just below 4½ per cent. Now it has already been shown that the financial yield on a 40-year rotation is 4·45 per cent., and it is easy to prove from the formulae that if the cost values and expectation values are worked out for any age less than the financial rotation with a rate of interest

TABLE XXXVI. *Cost and expectation values of a plantation at 20 years.*

Rate of interest. per cent.	*Cost value. mks.*	*Expectation value. mks.*
3	486	816
4	574	670
4½	623	609
5	676	551

equal to the financial yield then the two values will be equal.[1] From this it appears legitimate to assess the value of immature plantations at the cost value or expectation value (since they are equal) worked out with a rate of interest equal to the financial yield at the financial rotation (in this case 4·45 per cent.).

The cost value of a complete series of 1 hectare each of all ages from 0 to 39 is the summation of the series

$$(S+C)\ 1{\cdot}0p^{q}+\frac{e}{{\cdot}0p}(1{\cdot}0p^{q}-1),$$

where q has values from 0 to 39. But for ages 30 to 39 we must deduct $T_{30}\times 1{\cdot}0p^{q-30}$ since a thinning, T_{30} (= 100 marks), is taken at 30 years which has helped to pay for some of the cost of the older plantations. This summation will be

$$(S+C)\frac{1{\cdot}0p^{40}-1}{{\cdot}0p}+\frac{e}{{\cdot}0p}\left(\frac{1{\cdot}0p^{40}-1}{{\cdot}0p}-r\right)-T_{30}\frac{1{\cdot}0p^{10}-1}{{\cdot}0p}$$

$$=(100+80)\frac{5{\cdot}707-1}{0{\cdot}0445}+\frac{6}{0{\cdot}0445}\left(\frac{5{\cdot}707-1}{0{\cdot}0445}-40\right)-100\frac{1{\cdot}546-1}{0{\cdot}0445}$$

$$=180\times 105{\cdot}6+134{\cdot}6\times 65{\cdot}6-100\times 12{\cdot}3$$

$$=26{,}650.$$

[1] If the cost value is put equal to the expectation value,

$$(S+C)\ 1{\cdot}0p^{20}+e\,\frac{1{\cdot}0p^{20}-1}{{\cdot}0p}=(Y_{40}+S)\frac{1}{1{\cdot}0p^{20}}+T_{30}\frac{1}{1{\cdot}0p^{10}}-e\,\frac{1{\cdot}0p^{20}-1}{{\cdot}0p\times 1{\cdot}0p^{20}}.$$

Multiplying each side by $1{\cdot}0p^{20}$,

$$(S+C)\ 1{\cdot}0p^{40}+\frac{e}{{\cdot}0p}(1{\cdot}0p^{40}-1{\cdot}0p^{20})=Y_{40}+S+T^{30}\,.\,1{\cdot}0p^{10}-\frac{e}{{\cdot}0p}(1{\cdot}0p^{20}-1)$$

$$S\,(1{\cdot}0p^{40}-1)=Y_{40}+T_{30}\,.\,1{\cdot}0p^{10}-C\,.\,1{\cdot}0p^{40}-\frac{e}{{\cdot}0p}(1{\cdot}0p^{40}-1)$$

$$S=\frac{Y_{40}+T_{30}\,.\,1{\cdot}0p^{10}-C\,.\,1{\cdot}0p^{40}}{1{\cdot}0p^{40}-1}-\frac{e}{{\cdot}0p},$$

And this is the equation which, by solution for p, gives the financial yield on a rotation of 40 years.

We may also estimate the expectation value of this complete series of age gradations. This is most simply done as follows: If this forest of 40 ha. is worked as a normal forest the net income will be the difference between income and expenditure. The income will be Y_{40} (the value of 1 ha. of final yield) + T_{30} (the value of 1 ha. thinned at 30 years) – C (the cost of planting 1 ha.) – $40e$ (the annual cost of managing 40 ha.). This $= 1400+100-80-40\times 6 = 1180$. If this income represents the interest on a capital which yields 4·45 per cent. then the capital value $= \frac{1180}{0\cdot 0445} = 26{,}500$. This value is slightly different from the cost value because the true financial yield on a 40-year rotation is a little less than 4·45 per cent. It is actually 4·44 per cent., and the value of the complete series of age gradations (1 to 39 years) may be taken as 26,600 marks. We can now proceed to calculate the value of a complete series of age gradations from 0 to 49 years.

The series from 0 to 39 years is valued at 26,600.

The sale value of the timber on 1 ha. of age 40 after thinning is 1,150, and of age 50 before thinning is 1,850. If the growth in value is constant between these ages the sum of the values of the timber on 1 ha. each of ages 40 to 49 is $\frac{1}{2}(11\times 1150+9\times 1850)$. To this we must add the value of 10 ha. of land which is 1,000 mks., therefore the value of 50 ha. covering the ages 0 to 49 is

$$26600+(11\tfrac{1}{2}\times 1150+9\times 1850)+1000 = 42{,}250.$$

Dividing by 40 and 50 respectively we see that the average value per ha. of a normal forest worked on a 40-year rotation is $\frac{26600}{40}$ $= 665$ marks, and of a normal forest worked on a 50-year rotation is $\frac{42250}{50} = 845$ marks. By continuing these processes to each successive decade the series of figures in Table XXXVII, column 3, is obtained.

This is not the only way of valuing a forest, but for accountancy purposes it is probably the most satisfactory. It assumes that a prospective purchaser is at liberty to cut all the timber that is marketable without delay, which can only be done if the forest is free from restrictions and not too large for immediate cutting. If the forest took 20 years to cut it would be worth rather less to a timber company, but for the use which is made of the figures in this chapter these reservations are not significant.

(4) The net income expressed as a rate of interest on the capital value. This rate of interest is obtained by the formula $p = \frac{I}{C} \times 100$, where I is the income in column 5 and C the capital in column 3. The result is given in column 7.

If column 7 is compared with column 2, which is the *financial yield*, also an expression of income as a percentage on capital, it will be seen that the two are equal for a 40-year rotation but at other rotations they are unequal, and column 7 is invariably lower than column 2. The rate of interest as computed in column 7 will here be called the *rate on realizable capital*, and the reason why the rate on realizable capital is not the same as the financial yield is as follows. The financial yield on a 100-year rotation is 3·80 per cent.; this means that if all costs of a single plantation are debited to a forest account at 3·80 per cent. compound interest and all income is credited at the same rate, then the two amounts exactly balance when the final yield at 100 years and the land have been sold. Translating this into terms of normal forest it means that if the capital value of the normal forest is the cost value computed with a rate of interest of 3·80 per cent. then the income from the normal forest is 3·80 per cent. of this capital. Now the *realization value* of a 40-year-old plantation is equal to the cost value computed with 4·45 per cent. compound interest, since if the plantation is felled then the investment yields 4·45 per cent. The realization value of a 40-year-old plantation is therefore greater than the cost value computed at 3·80 per cent. compound interest, and is thus greater than the value allowed to it in estimating the financial yield on a 100-year rotation. The same is true of all other ages, so that the realization value of the normal forest as a whole is greater than the value allowed to it when the financial yield of 3·80 per cent. is calculated. The *rate on realizable capital*, on the other hand, is the rate of interest which the net income represents on the realizable capital of the forest and is thus lower than the financial yield.[1] The distinction between these two rates of interest has its parallel in ordinary modern investment. If an investor buys bonds at 20*s.* which yield 9 per cent., and these bonds subsequently

[1] It should be noted that what is here called the realizable capital of the forest is slightly higher than the amount that could be obtained from felling it since a value has been given to immature plantations, i.e. those under 40 years. If, however, no value were attached to plantations under 40 years the average capital value per hectare of a normal forest conducted on a 100-year rotation would still be 1,554 marks, on which capital the net income represents a return of 3·59 per cent. This is also below the financial yield.

TABLE XXXVII. *Figures calculated from Schwappach's money yield table for Scots pine, Quality II.*

Rotat. Years.	*Financial Yield. %*	*Capital value per ha. mks.*	*Capital incr. mks.*	*Annual income. mks.*	*Income incr. mks.*	*Ann. inc. as % of capital.*	*Inc. incr. as % of cap. incr.*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
30	3·90	503		18·0		3·58	
			162		*11·5*		*7·10*
40	4·45	665		29·5		4·44	
			180		*6·9*		*3·83*
50	4·40	845		36·4		4·31	
			190		*5·4*		*2·84*
60	4·30	1,035		41·8		4·04	
			190		*3·2*		*1·68*
70	4·10	1,225		45·0		3·67	
			192		*3·6*		*1·87*
80	3·95	1,417		48·6		3·43	
			198		*4·0*		*2·02*
90	3·85	1,615		52·6		3·25	
			205		*3·1*		*1·51*
100	3·80	1,820		55·7		3·06	
			210		*2·6*		*1·24*
110	3·70	2,030		58·3		2·87	
			206		*2·5*		*1·21*
120	3·65	2,236		60·8		2·72	
			207		*1·4*		*0·68*
130	3·60	2,443		62·2		2·54	
			202		*0·2*		*0·10*
140	3·55	2,645		62·4		2·36	

appreciate in value to 30*s.* then the investor receives 9 per cent. on his original investment but only 6 per cent. on the market value of the shares. In the same manner, if a normal forest managed on a 100-year rotation has been created, and costs and returns follow the premises of this chapter, then the owner is obtaining a yield of 3·80 per cent. on the money invested in the forest but only 3·06 per cent. on the market value of the forest. This distinction only arises when the rotation in the forest is different from the financial rotation.

The principle of diminishing returns applied to the length of rotation. The longer the rotation in a normal forest of given type the greater is the capital invested in it per hectare or per acre. Also the longer the rotation, up to a point (viz. the rotation of highest income), the greater is the net income per hectare or per acre. Now let it be supposed, for the use of abstract reasoning, that the length of rotation can be changed at will. It will then be seen (Table

XXXVII, columns 4, 6, and 8) that for each increase of 10 years in rotation from 40 to 140 years there is an increase of from 180 to 210 marks per hectare in the capital invested and an increase of from 6·9 to 0·2 marks per hectare in net income. Each additional dose of capital yields an additional dose of income and each dose of income can be expressed as a rate of interest on the corresponding capital.

To make this clear the relevant figures are extracted from Table XXXVII, and entered separately in Table XXXVIII. The figures

TABLE XXXVIII. *Rates of interest earned on successive doses of capital necessary to increase rotation in normal forest.*

Change in rotation.	*Capital increase per hectare.* mks.	*Income increase per hectare.* mks.	*Rate of interest earned on increase of capital.* %
30–40	162	11·5	7·10
40–50	180	6·9	3·83
50–60	190	5·4	2·84
60–70	190	3·2	1·68
70–80	192	3·6	1·87
80–90	198	4·0	2·02
90–100	205	3·1	1·51
100–110	210	2·6	1·24
110–120	206	2·5	1·21
120–130	207	1·4	0·68
130–140	202	0·2	0·10

are not quite continuous and no attempt has been made to 'smooth' them. But it remains clear, in general, that each additional dose of capital yields a smaller return than the last, so that the table demonstrates in a striking manner the law of diminishing returns. Up to 40 years, the financial rotation, the yield of each capital dose is greater than the highest financial yield obtainable on the whole rotation, i.e. 4·44 per cent.; but beyond 40 years each dose yields a lower return than 4·44 per cent., and the yield of successive doses becomes progressively smaller. In agriculture and other industries it is customary to apply additional doses of capital up to a point when they cease to yield a satisfactory return. In this case 4·44 per cent. is the highest financial yield that can be obtained, and since under present conditions this is lower than the rate of interest that can be earned on other investments, purely financial considerations would lead us to forgo the application of further financial doses of capital when they ceased to yield this rate of interest.

This analysis provides a new definition for the rotation of highest

income. *It is the rotation at which any money invested in lengthening the rotation still further would yield no return.* In the case of Scots pine, Quality II, with the data used in this chapter the rotation of highest income is approximately 140 years, and it is probable that, if the rotation were further lengthened, the income per hectare would be reduced though the capital invested would be increased.

The rotation of highest income has frequently been advocated as having a financial *raison d'être*. This is entirely fallacious and, though there may be good reasons for employing a rotation in excess of the

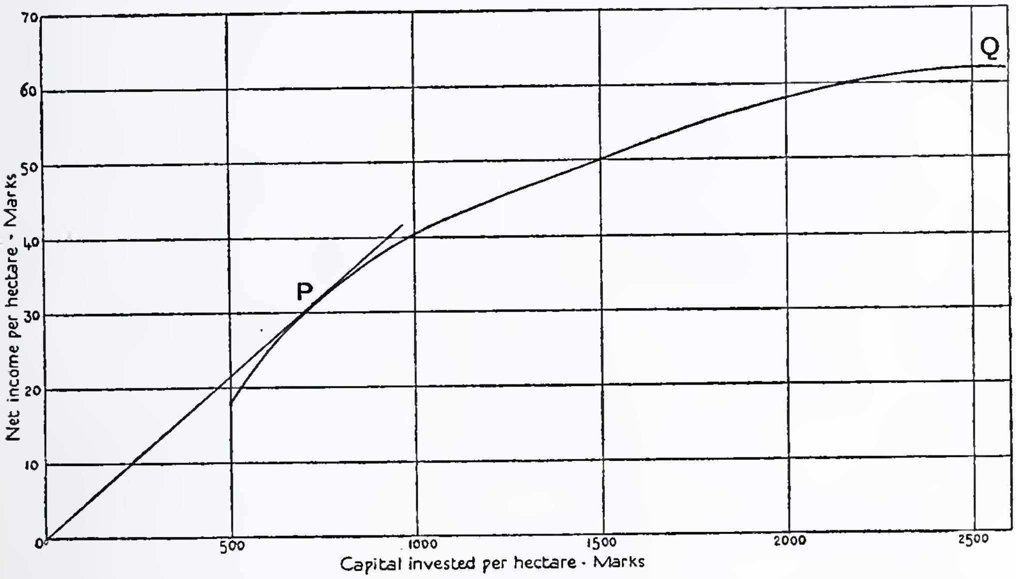

FIG. 17. Relation between capital invested per hectare in a normal forest and the income derived from it at various rotations (Scots pine, Quality II, Schwappach).

financial rotation, the rotation of highest income, as such, has no financial attractiveness, and should therefore not be made a basis for fixing the rotation.[1]

The graph in Fig. 17 shows the relation between the capital invested per hectare in a normal forest and the net income derived from this capital. The highest rate of interest is received when the proportion of income to capital is at its maximum, i.e. where the tangent through the origin strikes the curve (*P*). This point on the curve represents the relation of income to capital at the financial rotation. The income is greatest at the point *Q*, and this point represents the relation of income to capital at the rotation of highest income.

[1] As is done to-day in many forests in central Europe and has been advocated in America (Chapman, *Forest Finance*).

XII
THE COST OF PRODUCING TIMBER

Difficulties of the method. Data of cost of land, planting, and annual maintenance. Method of working. Results: cost of production, per cubic foot, of trees of various sizes of Scots pine, Corsican pine, Norway spruce, Sitka spruce, Douglas fir, European larch, and oak on various site qualities.

Difficulties of the method. In this chapter an attempt is made to estimate the actual *cost of production per cubic foot* of timbers of various species on land of each quality class. This method is attractive because it presents the results of calculations in a form which is easily understood, but there are two difficulties which have stood in the way of such a method of expression and have prevented its use in the past. The first difficulty is that by far the largest part of the cost of production of timber is represented by compound interest on the money invested in land, labour, and material, so that the calculated cost of production is greatly affected by the *rate* at which interest is charged to this capital. The second difficulty is that the cost of production of a final crop will depend on the amount of money which has been received for thinnings. This is especially important in the case of larch, and, on Quality I larch soils where there exists a good market for thinnings, the whole cost of production, including interest, may be met by the sale of thinnings, so that the cost of the final crop may be nil. This difficulty is not confined to forestry, and it is well known that the cost of producing coal-gas depends on the sale of by-products of the gasworks and the cost of producing wool depends on the price of mutton.

In the present chapter an attempt is made to meet these difficulties. The rate of interest that should be charged is largely a matter of opinion, but it will be generally accepted that for profitable working the rate should be somewhere between 3 and 5 per cent. Calculations have been made at 3, 4, and 5 per cent., and if the reader attaches particular weight to the actual figures of the cost of production he must make his own choice as to which rate of interest should be charged. As, however, the value of these calculations is comparative rather than absolute, comparisons may be made of the cost of producing various timbers at the same rate of interest, and the actual rate chosen is not of very great importance.

The difficulty of the relative price of thinnings and final crop has been met by assuming that the standing price of timber bears a definite relation to the size of tree, and that the price for thinnings is about three-quarters of that of a main crop with the same

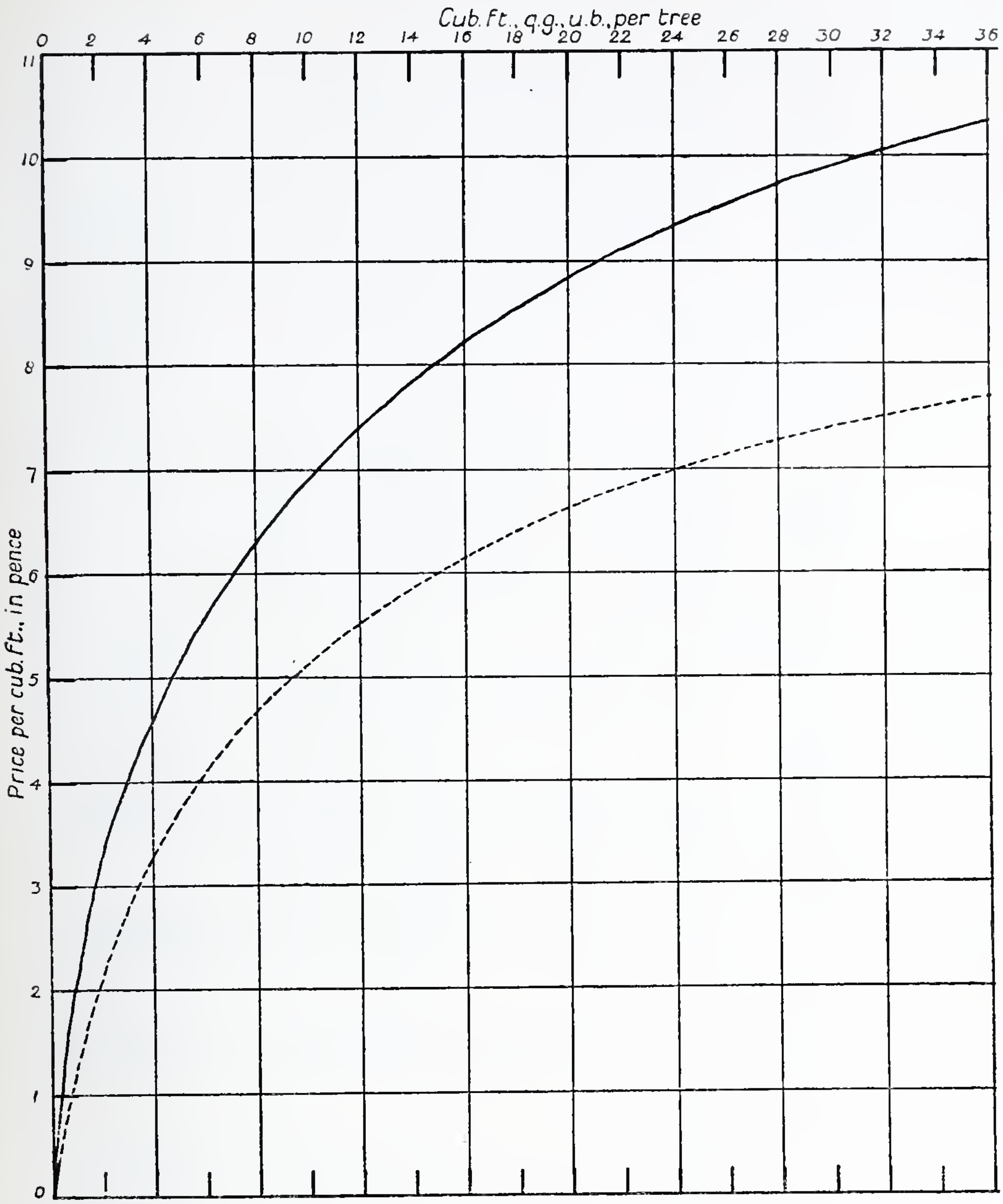

Fig. 18. Standard Prices. Relation between price per cubic foot and volume of average tree in cubic feet.

——Main Crop. --------Thinnings.

average sized tree. The size-price relationship which has been adopted as a basis is that used for Scots pine in *Oxford Forestry Memoir*, No. 6,[1] which is shown in Fig. 18. Owing to the method

[1] W. E. Hiley, 'Financial return from the cultivation of Scots and Corsican pines', *Oxford Forestry Memoir*, No. 6, 1926.

Table XXXIX. *Money yield table for Norway spruce, Quality I, with Scots pine standard prices.*

	Main crop.						Thinnings.					Final yield.
Age in years.	*No. of stems per acre.*	*Vol. per acre c.f.*	*Vol. per tree. c.f.*	*Price per c.f. d.*	*Value per acre. £*	*Value less 30 % £*	*No. of stems per acre.*	*Vol. per acre c.f.*	*Vol. per tree c.f.*	*Price per c.f. d.*	*Value per acre. £*	*Value. £*
25	1,080	2,400	2·2	3·3	33·0	23·1	—	—	—	—	—	—
30	710	3,500	4·9	5·1	74·4	52·0	370	410	1·1	1·4	2·4	54·4
35	535	4,400	8·2	6·3	115·5	80·8	175	440	2·5	2·3	4·2	85·0
40	410	5,250	12·8	7·5	164	115	125	485	3·9	3·1	6·3	121
45	335	6,030	18·0	8·5	214	150	75	490	6·5	4·2	8·6	159
50	280	6,760	24·1	9·3	262	183	55	470	8·5	4·8	9·4	192
55	240	7,420	30·9	10·0	309	216	40	445	11·1	5·3	9·8	226
60	210	8,020	38·2	10·5	351	246	30	415	13·8	5·8	10·0	256
65	190	8,530	44·9	10·7	380	266	20	345	17·2	6·3	9·0	275
70	175	8,960	51·2	11·0	410	287	15	320	21·3	6·7	8·9	296

of working the actual prices shown in this graph are of no significance; what is retained is the relationship between the price at any size and the price of all previous thinnings. This point will become clearer by an example of the method adopted.

Data of cost of land, planting, and annual maintenance. Calculations are based on money yield tables constructed from the British Yield Tables[1] in the manner explained in Chapter IX. It is assumed that 70 per cent. efficiency is attained, and main crop yields, but not thinnings, have been reduced by 30 per cent. As an example, the money yield table for Norway spruce, Quality I, is shown in Table XXXIX.

It is next necessary to take some values for the price of land, cost of planting, and cost of annual management. Table XL shows the

TABLE XL. *Price of land, cost of planting, and cost of annual maintenance per acre for various species.*

Species.	*Quality class.*	*Price of land.*	*Cost of planting.*	*Annual maintenance.*
		£	£	s.
Scots pine	I	3	5	12 or 8
	II	2	5	do.
	III	1	5	do.
Corsican pine	I	3	7	12 or 8
	II	2	7	do.
	III	1	7	do.
Norway spruce	I	6	7	12 or 8
	III	4	7	do.
	V	2	7	do.
Sitka spruce	I	6	8	12 or 8
	III	4	8	do.
	IV	3	8	do.
European larch	I	6	10	12 or 8
	III	4	10	do.
	V	2	10	do.
Douglas fir	I	7	9	12 or 8
	III	4	9	do.
	IV	3	9	do.
Oak	I	6	12	20 or 10
	III	2	12	do.

1 *Forestry Commission Bulletin*, No. 10, 1928.

amounts that have been inserted for these costs. The cost of land should include the cost of clearing scrub and any draining which need not be repeated in a subsequent rotation. The cost of planting includes fencing, plants, and planting, but not beating up, weeding, or overheads. The prices are rather lower than can generally obtain on private estates, but are fairly normal for the Forestry Commission.

The cost of annual management includes all overheads (less the value of sporting rents) and costs of general upkeep. It also includes the cost of cleaning and beating up in the early years, unremunerative thinnings in early middle life, and rides which become necessary for extraction at the end of the rotation. It is assumed that these costs are constant throughout the rotation, though in practice this may not be the case; but the inclusion of the cost of beating up and cleaning in maintenance rather than planting helps to equalize out the cost of annual management. The cost of management is higher for some situations and some species than for others; e.g. less beating up will be required for Scots pine than for larch. On the other hand, there may be no unremunerative thinnings with larch, whereas with Scots pine they can scarcely be avoided. Also, fire protection is more expensive on dry pine soils than on wet spruce soils. However, the same cost of maintenance has been used for each species, with the exception of oak, as it is very difficult to distinguish between them. It is difficult to say whether the cost of maintenance is likely to be higher or lower on the Forestry Commission areas than it is on private estates; in the former case overhead charges will almost certainly be more severe, but this will be largely compensated for by the greater ease of managing large areas.

Method of working. The following example refers to Norway spruce, Quality I, on a rotation of 55 years, on which the average size of tree is 30·9 c.f. The equation on which it is based is the Faustmann equation,

$$S = \frac{Y_r + \Sigma T_a \,.\, 1{\cdot}0p^{r-a} - C \,.\, 1{\cdot}0p^r}{1{\cdot}0p^r - 1} - \frac{e}{\cdot 0p}$$

this may be written $S = X - Z,$

where $$X = Y_r\left(\frac{1}{1{\cdot}0p^r - 1}\right) + T_a\left(\frac{1{\cdot}0p^{r-a}}{1{\cdot}0p^r - 1}\right) + \ldots$$

and $$Z = C \,.\, \frac{1{\cdot}0p^r}{1{\cdot}0p^r - 1} + e \,.\, \frac{1}{\cdot 0p}.$$

The amount summed up under X is determined by the value of main crop and thinnings, each multiplied by its appropriate factor;

the amount Z is the sum of the costs of planting and management again multiplied by their appropriate factors. The multipliers are taken from a schedule similar to those on p. 247.

		3%		4%		5%	
		Multiplier.	£	*Multiplier.*	£	*Multiplier.*	£
Y 55	226·	0·2450	55·4	0·1308	29·6	0·0733	16·6
T 30	2·4	0·513	1·2	0·349	0·8	0·248	0·6
T 35	4·2	0·442	1·9	0·287	1·2	0·195	0·8
T 40	6·3	0·382	2·4	0·235	1·5	0·152	1·0
T 45	8·6	0·329	2·8	0·194	1·7	0·119	1·0
T 50	9·4	0·284	2·7	0·159	1·5	0·094	0·9
X . . .			66·4 (34·7)		36·3 (28·9)		20·9 (25·5)
C	7·0	1·24	8·7	1·13	7·9	1·07	7·5
e	0·6	33·3	20·0	25·0	15·0	20·0	12·0
Z . . .			28·7		22·9		19·5
$S=X-Z$ . .			37·7 (6)		13·4 (6)		1·4 (6)

These calculations are exactly similar to the financial yield calculations on p. 141, and they show that, with the prices assumed in the money yield table, £13·4 per acre might have been paid for the land and 4 per cent. compound interest earned on the investment. If under the 4 per cent. column X had been 28·9 instead of 36·3, S would have been 6 instead of 13·4. Therefore, if £6 per acre had been paid for the land (as in Table XL), 4 per cent. could still have been earned on the plantation if X summed to 28·9, i.e. if all the prices for final yield and thinnings had been $\frac{28\cdot 9}{36\cdot 3}$, i.e. 0·796 times the prices assumed in the money yield table. Actually the price assumed for trees of this size (30·9 c.f.) was 10·0*d.*, so that to earn 4 per cent. it would have been sufficient if the price had been 8·0*d.*, and this figure may be regarded as the cost of producing spruce of this size on Quality I sites costing £6 per acre if 4 per cent. is charged to capital.

In the same manner a tree of 12·8 c.f. should be produced on a 40-year rotation at a cost of 6·6*d.*, and a tree of 8·2 c.f. on a 35-year rotation at a cost of 6·4*d.* per c.f. Combining these values by a graph it appears that the cost of producing a 10 c.f. tree is 6·5*d.*, a 20 c.f. tree is 7·0*d.*, and a 30 c.f. tree 7·9*d.* per cubic foot.

Calculations have been made in this manner for Scots pine, Corsican pine,[1] Norway spruce, Sitka spruce, and Douglas fir, and

[1] The volume of thinnings for Corsican pine has been taken from *Oxford Forestry Memoir*, No. 6, 1926, as calculations are here used which were made for that memoir before the British Yield Tables of 1928 were published.

the results are shown in Table XLI. Larch had to be treated in a special manner as the cost of production of larch timber is greatly reduced by the high price which can be obtained for thinnings. This price varies greatly from place to place, and in these calculations it has been assumed that, corresponding to a price of 1*s.* 4*d.* per cubic foot for a tree of 20 c.f., thinnings have been sold for 2*d.* each at 15 ft. high (total height), 3*d.* at 25 ft., 4½*d.* at 35 ft., and 6*d.* at 45 ft. Where, as happens not infrequently, the thinnings can be sold for three or four times these prices the cost of production of timber trees will be much lower.

TABLE XLI. *Cost of production, per cubic foot, of various timbers of various sizes in Britain.*

			Price per cubic foot required to earn					
			3%		4%		5%	
Species.	*Quality class.*	*Size of tree. c.f.*	*e=12s.*	*e=8s.*	*e=12s.*	*e=8s.*	*e=12s.*	*e=8s.*
			s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Scots pine	I	10	8·7	6·7	1 1·0	10·3	1 7·3	1 3·6
		20	11·4	8·7	1 7·6	1 2·7	2 8	2 1
		30	1 2·8	11·1	2 2	1 10·4	4 1	3 4
	II	10	11·6	8·8	1 6·3	11·8	2 5	1 4·6
		20	1 4·0	1 0·1	2 4	1 9·5	4 4	3 7
		30	1 10·3	1 4·9	3 8	2 10	7 6	5 11
	III	10	1 5·4	1 1·2	2 10	1 10·2	4 2	3 3
		20	2 2·4	1 7·8	4 3	3 3	9 3	7 3
Corsican pine	I	10	4·8	3·8	6·3	5·1	8·6	7·0
		20	5·6	4·3	8·2	6·3	11·7	9·4
	II	10	6·5	5·0	9·2	7·2	1 1·0	10·4
Norway spruce	I	10	4·8	3·9	6·5	5·5	8·8	7·5
		20	4·9	4·0	7·0	5·9	10·3	8·7
		30	5·1	4·2	7·9	6·5	1 0·0	10·1
	III	10	7·2	5·7	10·4	8·5	1 3·1	1 0·5
		20	8·3	6·6	1 1·2	10·6	1 9·6	1 5·8
		30	9·9	7·7	1 4·8	1 1·7	2 5	1 11·9
	V	10	1 2·5	11·2	2 0	1 7·1	3 5	2 10
Sitka spruce	I	10	2·9	2·5	3·8	3·3	4·9	4·2
		20	3·1	2·6	4·1	3·5	5·7	4·7
		30	3·3	2·7	4·6	3·8	6·5	5·4
	III	10	4·3	3·5	5·6	4·7	7·5	6·3
		20	4·5	3·6	6·3	5·1	8·8	7·4
		30	4·7	3·8	7·0	5·8	10·5	8·9
	IV	10	5·6	4·6	7·5	6·2	10·4	8·7
		20	5·9	4·8	8·7	7·1	1 1·0	11·0

Species.	Quality class.	Size of tree. c.f.	Price per cubic foot required to earn 3% e=12s.	3% e=8s.	4% e=12s.	4% e=8s.	5% e=12s.	5% e=8s.
			s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Douglas fir	I	10	3·6	3·1	4·5	3·9	6·0	5·0
		20	3·5	3·0	4·8	4·0	6·3	5·3
		30	3·7	3·1	5·1	4·2	6·7	5·9
	III	10	4·3	3·6	5·7	4·8	7·3	6·3
		20	4·7	3·9	6·5	5·4	8·9	7·5
		30	5·0	4·1	7·1	5·9	10·1	8·5
	IV	10	5·5	4·6	7·2	6·0	9·7	8·2
		20	5·8	4·7	7·9	6·5	11·1	9·3
		30	5·8	4·6	8·5	7·0	1 0·3	10·3
European larch	I	10	6·0	5·0	8·0	6·8	10·7	9·3
		20	7·0	5·8	8·3	8·7	1 2·7	1 0·8
		30	8·3	6·9	1 0.9	10·9	1 7·3	1 4·6
	III	10	10·6	8·7	1 3·5	1 1·1	1 10·3	1 7·2
		20	1 2·2	11·4	1 10·0	1 7·7	2 10	2 5
	V	10	2 1	1 8·2	3 8	2 11	5 10	4 11
			e=20s.	e=10s.	e=20s.	e=10s.	e=20s.	e=10s.
			s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Oak	I	10	2 0	1 5	3 1	2 3	4 10	3 7
		20	2 1	1 5	3 6	2 6	5 10	4 4
		30	2 3	1 7	4 0	2 10	7 2	5 4
	III	10	4 7	3 0	8 7	5 10	16 1	11 4
		20	5 11	3 11	12 2	8 3	23 0	16 7
		30	7 8	5 0	15 9	10 8	30 0	21 0

Results. Table XLI, which shows all the costs of production computed on these data, contains so many figures that it is rather confusing. The costs per cubic foot of the trees of 20 c.f. at 4 per cent. compound interest have, therefore, been picked out and are given in Table XLII. From these tables the following conclusions may be drawn.

TABLE XLII. *Cost, per cubic foot, of producing trees of* 20 *c.f. at* 4 *per cent. interest. (Cost of annual management* 12*s. per acre for conifers and* 20*s. for oak.)*

Quality of site.	Scots pine.	Corsican pine.	Norway spruce.	Sitka spruce.	Douglas fir.	European larch.	Oak.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Good . . .	1 7½	0 8¼	0 7	0 4	0 4¾	0 8¼	3 6
Intermediate . .	2 4	—	1 1¼	0 6¼	0 6½	1 10	—
Poor . . .	4 3	—	—	0 8¾	0 8	3 8	12 2

1. The cost of producing timber is much less on good than on poor quality land even when the cost of the land is taken into account. In other words, the market price of land is not proportional to its value as a basis of cultivation. The same generalization has been observed in the case of agriculture, and it appears to be applicable over a wide range of cultivation. It follows from this that in order to produce as cheaply as possible it is necessary to select the best possible sites. But foresters are generally debarred from using land which has an appreciable agricultural value and are therefore confined to the cheaper soils. In Britain, however, there are two ways of countering this handicap, and, for a discussion of this subject the reader is referred to p. 205.

2. The various species differ greatly in their cost of production. Sitka spruce and Douglas fir are by far the cheapest to produce and, since Sitka spruce thinnings may under favourable circumstances be used for pulp and Douglas fir for many of the uses to which larch is at present put, the costs of production will probably prove to be lower than those shown in the table.

Sitka spruce costs about one-half to one-third as much as Norway spruce, and since the timbers appear to be of equal value and the species require similar conditions in Britain it may be questioned whether Norway spruce should ever be grown.

Corsican pine bears about the same relation to Scots pine as Sitka spruce bears to Norway spruce, but it appears that the timber of Scots pine is definitely better than that of Corsican. It is worth while to make a very great effort to grow Douglas fir rather than Scots pine, and a 4th quality Douglas fir plantation is likely to be more remunerative than a 1st quality Scots pine plantation. The ease of establishing Scots pine is a facile snare for the uninitiated.

The cost of growing European larch is very greatly influenced by the price at which thinnings can be sold, and too much weight must not be attached to the costs of production given in the table. As a ready market can always be found for this timber, generally at very favourable prices, larch must be considered one of the most profitable conifers to grow.

The cost of production of oak is based on Qualities I and III of Schwappach's volume yield table for Prussia.[1] The rate of growth represented by Quality I is about equal to that of Quality II of Wimmenauer's Table which was converted into English measure by Schlich in Volume III of his manual, and it represents a total

[1] *Untersuchungen über die Zuwachsleistungen von Eichen-Hochwaldbeständen in Preussen*. Neudamm, 1905. See Appendix II of this volume.

growth of 9,095 c.f., q.g. per acre in 100 years. This is probably equivalent to the best growth in Britain. Schwappach's Quality III shows a total growth in 100 years of 5,100 c.f., q.g. of which half is removed as thinnings. Quality I takes 85 years and Quality III 135 years to produce an average tree of 30 c.f.

In reading the calculated costs of production from the tables it should be remembered that a high cost of production presupposes a proportionately high sale price for thinnings and a low cost of production a proportionately low sale price for thinnings. Thus, when it is shown that, on Quality III sites, oak of 20 c.f. costs 12*s.* 2*d.* per c.f. to produce, this presupposes that thinnings of 5 c.f. can be sold for 5*s.* per c.f.; whereas, production of Sitka spruce on Quality I sites is possible at 4*d.* per c.f. if thinnings of 5 c.f. fetch only 1¾*d.* per c.f. This system of proportional prices has been adopted because it is less objectionable than assuming fixed prices for thinnings, since no fixed prices would be of general application. If, however, actual prices were inserted for thinnings the cost of production of Sitka spruce and Douglas fir should be lower, and that of Scots pine and oak higher, than the figures in the tables.

The results of these calculations are distinctly encouraging to British forestry, and it appears that, if good management is assured, a return of 4 per cent. may be expected, on an average, from capital invested in planting, and higher rates of interest in favourable localities. As this return is very nearly free of income-tax and super-tax the investment may be considered attractive from the point of view of the private landowner.

XIII

THE COMPARATIVE PROFITABLENESS OF VARIOUS SPECIES

The variables of forestry. Species—Conifers: larches; pines; spruces; Douglas fir; *Abies grandis*; *Thuya plicata*; *Cupressus macrocarpa*. Broad-leaved species: oak; beech; ash; poplar; coppice. Mixtures: oak and beech; larch thinnings for profit; larch and Douglas fir: underplanting.

The variables of forestry. Some forms of forestry are very much more profitable than others. On any given estate a forester is in large measure circumscribed in his methods; he cannot greatly alter the quality of his planting sites, and his choice of species must be largely determined by the kind of land which he has to cultivate; markets may be distant and, despite his best efforts, extraction may be expensive.

At the same time there are many factors which are within the control of the forester. There is always some measure of choice in the selection of species; rotation and density of planting are entirely within human control; and, even as regards markets, a keen forester will obtain much better prices than one who is unenterprising or indolent.

In this chapter the influence of various factors on profitableness is discussed, examples being drawn principally from British forestry.

Species—conifers. The natural coniferous forests in Britain are confined to a few areas of Scots pine in Scotland. All the coniferous woods in England and Wales and most of those in Scotland have been initiated by planting, and their silvicultural treatment is far more standardized than it is on the continent. Until the advent of the Forestry Commission in 1919 nearly all the plantations were privately owned, and many years must elapse before the state-owned plantations are equal in area to the plantations on private estates. Consequently, the units of management are generally small and their administration lacks that continuity which is desirable if successful economic results are sought after.

Owing to the fact that only a very small proportion of British territory is covered by woodland and to the great density of our population, the markets for forest products in Britain are, on the whole, very good. This applies particularly to the lighter products, such as small thinnings, which have to meet less foreign competition than large timber. Estates situated a few miles from

towns or mines are particularly favoured in this respect, and it will be shown that this has a very important influence on the economics of the cultivation of certain species, especially larch.

In the following notes on the economic returns that may be anticipated from coniferous plantations all the results are expressed in terms of the financial yield. Owing to the manner in which woodlands are taxed in Britain these financial yields are very nearly tax free rates of interest on capital invested. If Forestry Commission grants[1] are obtained for planting these are, in most cases, equivalent to a remission of all taxes. The financial yields given for various species are based on certain data of costs and returns, and in each case these data are specified. They are based on results obtained on well-managed estates, and, though inexperienced foresters may find their costs higher, enterprising managers should in many cases be able to reduce their costs below the figures given. For the method of arriving at data the reader is referred to chapter vii.

THE LARCHES. The European larch (*Larix europaea*) has for many years been the favourite tree for planting on the better soils of private estates, and its popularity is fully justified on financial grounds. The European larch is not a rapid volume producer, its increment being much less than Norway spruce or any of the more popular conifers from western America; its volume increment is about equal to that of Scots pine, which is a far less profitable tree. The value of larch lies in the durability of its timber when exposed to weather, for even small thinnings last many years in the open. This, together with the absence of large branch scars which disfigure small thinnings of pines and spruces, gives the thinnings a ready market for garden work, fencing, hop poles, &c., and the larger thinnings are preferred to other species in mines. Small thinnings are sold by the pole and not the cubic foot; sold in this way the actual price may work out at 3*s.* to 4*s.* per cubic foot. Large timber sells for about 50 per cent. more per cubic foot than Scots pine and about 100 per cent. more than spruce, and prices as high as 1*s.* 6*d.* per cubic foot are sometimes obtained for really good lots. Owing to the high price obtained for small thinnings larch is sometimes grown on short rotations of 20 to 30 years. European larch is particularly liable to heart-rot and canker, and successive rotations on the same site are deleterious to the soil.

[1] These at present may be granted up to £2 per acre for conifers, £4 for oak or ash, £3 for beech, sycamore, or chestnut, and £2 for other approved hardwoods. Additional grants are available for clearing worthless scrub areas, if not less than 50 acres, for planting.

In recent years Japanese larch (*Larix leptolepis*) has frequently been used as an alternative to European larch. Up to 20 years of age it is considerably faster in growth than the European species, and it is a rapid producer of small sized timber. It is also immune from canker, and in many parts of the country it produces straighter stems than European larch. There is very little evidence as to its rate of growth in later years, but there is reason to believe that European larch overtakes it at about 30 years. Japanese larch may, therefore, be preferred when it is desired to grow larch on short rotations; it should, however, only be planted on retentive soils as it is sensitive to drought.

The Dunkeld hybrid larch (*L. eurolepis*) is a presumed hybrid between *L. leptolepis* (♀) and *L. europea* (♂). The first generation has proved itself in Scotland to be still more rapid in growth than *L. leptolepis*, but seed is difficult to obtain.

The profitableness of larch cultivation is greatly influenced by the markets for thinnings. In some of the northern counties there is a great demand for small thinnings for agricultural fencing; this is particularly the case in districts where hunting is in vogue and barbed wire is objected to. In other parts of the country there is generally a good market for garden purposes near towns.

In order to demonstrate the influence of high prices for early thinnings on the financial returns, financial yields have been worked out from a money yield table for European larch, Quality II, which is constructed with the same prices for timber as in Table XXX, p. 127, but with the following prices for poles.

Ht. of tree in feet.	*Price per pole, standing, in pence.*
15–20	6
20–25	9
25–30	12
30–35	18
35–40	24
40–45	30
45–50	36

With such prices the value of the main crop is enhanced up to 30 years, and the value of the thinnings up to 45 years. Table XLIII shows the financial yields obtainable under these conditions and, for comparison, the yields with a poor market for small thinnings are also given.

TABLE XLIII. *Financial yields for European larch, Quality II, with good and poor markets for small thinnings.* ($C = £10$, $e = 12s.$)

Rotation (years).	20	25	30	35	40	45	50	60	70	80
					Financial yield.					
	%	%	%	%	%	%	%	%	%	%
Land worth £5 per acre										
With good market	7·0	7·3	7·4	7·4	7·3	7·2	7·1	6·9	6·7	6·5
With poor market	—	2·9	4·0	4·4	4·5	4·6	4·5	4·3	4·0	3·8
Land worth £10 per acre										
With good market	6·1	6·4	6·5	6·6	6·6	6·5	6·3	6·1	5·9	5·8
With poor market	—	2·5	3·6	3·9	4·0	4·1	4·0	3·9	3·7	3·6
Land worth £20 per acre										
With good market	4·9	5·2	5·4	5·5	5·5	5·5	5·4	5·2	5·0	4·8
With poor market	—	1·9	2·9	3·2	3·4	3·5	3·4	3·3	3·2	3·1

From this table will be seen the profound influence that a good market for thinnings has on financial returns. It is more profitable to plant land costing £20 per acre where markets are good than land costing £5 per acre where markets are poor. In fact 4·5 per cent. could be obtained on land costing £35 per acre if the above prices for small thinnings held good. It should be remembered that markets depend not only on position but, just as much, on business management, and a capable forester will obtain markets in areas in which others will be unable to sell.

The financial return that may be obtained from larch plantations depends not only on the available markets but on the rate of growth of the plantations themselves, i.e. on the quality class of the site. Calculations have been made from money yield tables constructed from the Forestry Commission Volume Yield Tables for all five quality classes, the cost of planting being assumed in each case to be £10 and the annual cost of management 12*s.* per acre and 70 per cent. efficiency being presumed for the main crop. If the land costs £10 per acre the results which are obtained are as shown in Table XLIV.

It will generally be found that land which grows larch rapidly costs more than land of poor quality class. Table XLV shows the price which can be paid for land of each quality class to allow financial yields of 6, 5, and 4 per cent. These amounts are the 'expectation values' of the land calculated at these rates of interest.

In Table XLV negative values imply that, in order to obtain the rate of interest shown, not only must the land be obtained free of charge but a bonus (e.g. the Forestry Commission grant in aid of

TABLE XLIV. *Financial rotation and financial yield for various quality classes of European larch.*

Quality class.	*Market for thinnings.*	*Financial rotation years.*	*Financial yield %.*
I	good	30	8·0
	poor	35	5·2
II	good	35	6·6
	poor	45	4·1
III	good	45	4·9
	poor	55	3·2
IV	good	55	3·8
	poor	70	2·3
V	good	more than 80	less than 2·0
	poor		

TABLE XLV. *Prices that can be paid (per acre) for larch land to yield certain financial yields.*

Quality class.		I	II	III	IV
		£	£	£	£
Good market for thinnings					
Price of land to yield	6%	27	15	1	—7
	5%	43	27	9	—2
	4%	69	46	21	6
Poor market for thinnings					
Price of land to yield	6%	4	—4	—	—
	5%	13	1	—6	—
	4%	28	11	1	—10

planting) must be available. The table shows that high rates of interest can only be obtained on good quality land, and it is more profitable to plant land costing £20 per acre if it grows first quality larch and is in a neighbourhood of good markets than to plant second quality land costing nothing in a locality where the market for thinnings is poor.

It is interesting in this connexion to note that among the larch sample plots used for the British Yield Tables[1] first and second qualities were represented by 86 per cent. in SE. England, 61 per cent. in SW. England, and 52 per cent. in W. Scotland. In N. England and E. Scotland the percentages were respectively 22 and 21. In SE. England only 2 per cent. were below third quality. These figures show that, at any rate in the south of England, very

[1] *Forestry Commission Bulletin*, No. 10, H.M. Stationery Office, 1928.

good financial returns can be looked for from larch when grown under suitable conditions.

Much of the coppice, coppice with standards, and scrub[1] which exist in the south of England may profitably be converted into larch plantations.[2] Such areas are generally cheap, unless they have prospective building value, and the chief cost of the land to the forester is due to the necessity for cleaning, for which some amount up to £10 per acre may have to be allowed. It is generally, however, much more profitable to plant such land than to afforest bare land of inferior quality which needs no clearing.

Owing to its rapid growth in early youth Japanese larch is particularly useful for growers who specialize in marketing stems up to pit-prop size. The Forestry Commission yield table for this species specifies two quality classes which give a mean height of 44½ and 33 ft. respectively at 20 years. The corresponding heights for European larch range from 40 to 14 ft. at this age and, though the Japanese species has no doubt been planted on the better soils, it is noteworthy that all the sample plots in the south of England (10 in number) belong to the first quality.

Japanese larch is especially adapted to the requirements of farmers who are desirous of planting up spinneys on their farms. If planted at 4 to 5 ft. useful fencing material may be obtained at 12 years, and a rotation of 20 years will provide posts up to 7 or 8 inches in diameter. Where there is a good market for small sizes short rotations of this species should give higher financial yields than any other form of forestry.

THE PINES. The Scots pine (*Pinus silvestris*) is the only native coniferous tree which is an important timber producer and, especially in Scotland, large quantities are cut each year.[3] The tree is adapted to light gravelly soils at low elevations, and is generally grown on soil which is unsuitable to any other form of cultivation. On such soils weed growth is not a serious difficulty and, consequently, one or two-year-old seedlings may be used for planting. The cost of planting should, therefore, be not more than £8 and may be as low as £5 per acre. The absence of weed competition also reduces the cost of annual management, except that on such areas fire is often a serious menace. The early thinnings from Scots pine are frequently

[1] In Kent, Surrey, Sussex, and Hants alone these areas amount to more than a quarter of a million acres. *Forestry Commission Census of Woodlands*, H.M. Stationery Office, 1928. [2] The drier sites will mostly grow European larch, the wetter Japanese larch.

[3] The estimated cut of Scots pine in 1924 was 12·7 million c.f. in Scotland and 4·0 million c.f. in England and Wales.

unsaleable as they contain very little heart-wood, and stakes quickly rot when exposed to weather. Stems, however, which are large enough to be squared and creosoted provide very useful material, and the sale of such timber depends primarily on the facilities for creosoting it.

A detailed analysis of the financial yields which may be expected from Scots pine plantations in England[1] shows that, even on very cheap land, the returns are very much lower than those from larch. The money yield tables from which these financial yields were estimated were based on the Forestry Commission yield tables for Scots pine (England) with prices corresponding to the graph on p. 177, 30 per cent. being deducted from calculated main-crop values for losses through fungi, insects, &c. If land costs £2 per acre, the following are the maximum values of the financial yields.

TABLE XLVI. *Financial yields for Scots pine.*

Quality class.	I	II	III
Financial rotation (yrs.)	*60–70*	*80*	*90*
$C=£7,\ e=12s.$	2·4%	1·8%	1·2%
$C=£5,\ e=12s.$	2·6%	2·0%	1·3%
$C=£7,\ e=8s.$	2·9%	2·3%	1·7%

It appears from these figures that, at present timber prices, no land can be profitably planted with Scots pine. Most foresters, however, look for some advance in the price of timber, and it has been calculated that a rise of 1 per cent. per annum in the price of standing pine would increase the financial yield by about 1·3 per cent., and an annual rise of 1½ per cent. in prices would increase the financial yield by about 2 per cent. Thus, if prices rose by 1½ per cent. per annum pine plantations on first quality sites might yield from 4½ to 5 per cent.

Corsican pine (*Pinus laricio corsicana*) is adapted to the same soils as Scots pine, but is less hardy as regards climate. In England it is found that Quality I Scots pine sites will grow Quality I Corsican pine, Quality II Scots pine sites will grow Quality II Corsican pine, and so on. Corsican pine has one very great advantage over Scots pine in that it is far more rapid in growth; on similar sites it produces almost 50 per cent. more timber than the latter species. It has two disadvantages; one is that, owing to the difficulty of transplanting it, plantations are more expensive to initiate, the other that the timber is knotty and difficult to season though it has good

[1] Hiley, 'The financial return from the cultivation of Scots and Corsican pines', *Oxford Forestry Memoir*, No. 6, 1926.

working properties. The market in Corsican pine timber cannot be adequately tested at the present time owing to the small quantities of mature timber available, but it is useful to know what prices would be necessary in order to make the cultivation of the one species more profitable than that of the other.

It has been shown[1] that if Corsican pine costs £1 per acre more than Scots pine to plant, and if the standing price for Corsican pine timber is 60 per cent. of that for Scots pine of the same size, then the two species are equally profitable on 1st or 2nd quality sites. The yield tables for Quality III are inadequate for comparative purposes. This relation is approximately true whether timber prices remain constant or rise and it is unaffected by variations, within the range of probability, in the cost of land, planting, and annual management. As it is generally anticipated that, when well grown, the price of Corsican pine timber will be more than 60 per cent. of that of Scots pine, it appears that Corsican pine is likely to prove the more profitable species to grow.

Both Corsican pine and Scots pine are subject to serious fungus and insect diseases, the most serious fungus pests in Britain being the honey fungus (*Armillaria mellea*) and certain heart-rots, and the most serious insect pest, *Tortrix buoliana*.

No other species of pine are grown on a commercial scale in Britain.

THE SPRUCES. None of the spruces have been grown on a large scale in Britain, and the prices obtainable for timber are uncertain. As, however, the volume produced by Norway spruce (*Picea excelsa*) is very nearly double that produced by Scots pine in the same period and as, in consequence, trees reach timber size in a shorter time, there can be no doubt that spruce is a more profitable tree when grown on suitable soils. As, however, the pines grow on light soils and the spruces on heavy soils the choice seldom lies directly between these species.

The suitability of spruce for the manufacture of sulphite pulp has made it a popular tree on the continent. The paper industry of Saxony has been built up on the extensive areas of spruce forest which have been planted there, and the fact that pulp mills have provided a ready market for thinnings has greatly enhanced the financial returns from these plantations.[2] Soil deterioration resulting from the cultivation of pure spruce stands and the attacks of nun

[1] Hiley, loc. cit. 1926.

[2] For comparative figures of the profitableness of spruce and pine in Germany see p. 214.

moth have, however, shown that the silvicultural problems of spruce cultivation have not yet been solved. The use of small spruce for pulpwood is such an important consideration in forest finance that even in Finland, where spruce growth is seldom better than Quality V of the British Yield Tables, this species is encouraged at the expense of pine.

In Britain there is as yet no market for spruce wood for pulp, but if large areas were planted for this purpose a market might be created, and one of the Forestry Commission schemes has this object in view. In the absence of this special market spruce is nevertheless more profitable than pine, and the average return from Quality I spruce woods is probably over 4 per cent. Where there is a market for pitwood this figure might be considerably exceeded.

Sitka spruce (*Picea sitchensis*) is being planted to an increasing extent in Britain, though few of the plantations are old enough to test the market for the timber. The tree has a restricted distribution in its native area in British Columbia and neighbouring states, but the imported timber obtained a very great reputation owing to its usefulness in the manufacture of aeroplanes. The grain of the wood is extraordinarily straight, and long, thin pieces have unusual strength for their weight. It is probable, however, that this particular quality is a characteristic of timber from old trees, and on the short rotations, which would be most profitable in Britain, trees cannot be expected to produce such a valuable commodity.

The popularity of Sitka spruce in Britain is due to its fast rate of growth combined with the belief that its timber will be at least as good as that of Norway spruce. Under similar conditions Sitka spruce yields about 40 per cent. more timber per acre per annum than Norway spruce; it also gets away much more quickly in youth and will produce utilizable thinnings at a far earlier age. As the tree grows on very heavy soils and can withstand high altitudes it appears to be one of the most useful we have, but as it requires a very moist climate—it only grows within 50 miles of the sea in British Columbia—the geographical limits to its use are somewhat narrow. Owing to its liability to damage by spring frosts it is unsuitable for planting in frost hollows.

Douglas Fir (*Pseudotsuga Douglasii*) has been extensively planted in Britain and has also been sparingly used on the continent. Unlike the Sitka spruce this species has a very wide natural distribution which spreads from the Pacific Coast to the eastern slopes of the Rocky Mountains and from Alaska to Colorado. The species is made up of many races, and owing to its wide range of variation it can

be adapted to most of the climates of north-west Europe. The following remarks apply to the green or Vancouver Douglas fir as grown from seed gathered near the mouth of the Fraser River in British Columbia.

In Britain the height growth of Douglas fir is more rapid than that of any other conifer. It is the only tree for which a 110 ft. quality class has had to be constructed in the British Yield Tables; that is to say, it is the only conifer which produces stands the average height of which is 110 ft. in 50 years. It is also a remarkable volume producer, and the total growth to 50 years may show a mean annual increment of 238 c.f. in 1st quality stands. The growth of the tree is very rapid in youth and, as the thinnings can often be marketed in the same manner, and for the same purposes, as larch, considerable early returns may be expected from plantations.

The timber of home-grown Douglas fir has so far been difficult to sell. It is as yet an unknown quantity in the timber market, and in any case the broad-ringed timber from young trees is very inferior to the narrow-ringed, clear timber sold on the Pacific slope under the name of 'Oregon pine'. If the price be placed at 10 per cent. less than Scots pine of the same size it appears that a financial yield of 7 per cent. may be expected from Quality I plantations on a 40-year rotation and about 5 per cent. from Quality III plantations on a 50-year rotation. This is without ascribing any special value to the thinnings.

Quality I plantations should have a volume of over 30 c.f. per tree in 40 years, and thus reach timber size before this age. But there may be difficulty in marketing this timber, and foresters are consequently becoming rather shy of growing it. If, however, the trees have to be grown on to an 80-year rotation in order to obtain satisfactory prices the growth of this species will still be very profitable, and in the meantime the thinnings should yield a very considerable income. It is sometimes contended that, whereas growing Douglas fir is a speculation, growing Scots pine is a safe investment. Financial analysis shows that whereas Scots pine may be expected to yield about 2 per cent. on the money invested in growing it, Douglas fir may be expected to yield over 5 per cent. Even if Douglas fir fetched only a third as much per cubic foot as Scots pine of the same size it would still be a much more profitable tree to grow, and it may consequently be considered a much safer financial investment than the latter species.

Douglas fir has been grown on a very wide range of soils. It is most at home on a porous loam under a heavy rainfall, but it grows

fairly well on clays, and successful experimental plantations exist on light soils under the dry conditions of East Anglia. In early youth it is sensitive to frost damage and it is intolerant of windy situations but, although much attention has recently been paid to its diseases, it is probably less damaged by insect and fungus pests than Scots pine.

TABLE XLVII. *Volume of maincrop, thinnings, total yield, and mean annual increments of conifers in Great Britain (from British Yield Tables for full stocking).*

(All measurements are quarter girth.)

	Quality class.	*Age. years.*	*Mean height. ft.*	*Vol. in cub. ft. per acre.* *Main-crop.*	*Thinnings.*	*Total.*	*Mean ann. increment. c.f.*
European larch	I (60)[1]	50	80	4,570	1,370	5,940	119
		80	100	6,070	3,090	10,160	102
	II (161)	50	70	3,700	1,110	4,810	96
		80	90	5,170	2,555	7,725	77
	III (144)	50	60	2,910	665	3,575	71
		80	79½	4,300	1,855	6,155	61
	IV (69)	50	50	2,160	490	2,650	53
		80	69½	3,470	1,475	4,945	49
	V (30)	50	40	1,460	165	1,625	32
		80	59	2,690	930	3,620	36
Japanese larch	I (34)	30	57½	3,200	—	—	107[2]
	II (22)	30	44½	2,295	—	—	76[2]
Scots pine England	I (61)	50	60	3,530	710	4,240	85
		100	84½	5,730	2,695	8,425	84
	II (152)	50	50	2,890	410	3,300	66
		100	74	5,130	2,045	7,175	72
	III (94)	50	40	2,190	180	2,370	47
		100	62	4,390	1,285	5,675	57
Scots pine Scotland	I	50	60	4,100	705	4,805	96
		100	84½	6,720	2,975	9,695	97
	II	50	50	3,450	425	3,875	77
		100	74	6,200	2,205	8,405	84
	III	50	40	2,540	210	2,750	55
		100	62	5,100	1,680	6,780	68

[1] The figures in brackets are the numbers of plots measured by the Forestry Commission which came into the various quality classes. The numbers for pine include England and Scotland. For European larch 10 plots were also measured below Class V; for Scots pine 8 above class I and 24 below Class III; for Norway spruce 2 below Class V.

[2] Without thinnings.

(*All measurements are quarter girth.*)

	Quality class.	Age. years.	Mean height ft.	Vol. in cub. ft. per acre. Main-crop.	Thinnings.	Total.	Mean ann. increment. c.f.
Corsican pine	I (21)	50	70	5,050	1,850[1]	6,900	138
	II (3)	50	60	4,330	1,480[1]	5,810	116
	III (3)	50	50	3,560	840[1]	4,400	88
Norway spruce	I (22)	50	80	6,760	2,295	9,055	181
		70	100	8,960	3,820	12,780	182
	II (34)	50	70	5,890	1,540	7,430	149
		70	87	7,800	2,775	10,575	156
	III (60)	50	60	4,930	900	5,830	117
		70	75	6,730	1,880	8,610	123
	IV (43)	50	50	3,900	370	4,270	85
		70	64½	5,660	1,105	6,765	97
	V (14)	50	40	2,820	200	3,020	60
		70	53	4,400	795	5,195	74
Sitka spruce	I (2)	50	100	9,350	—	—	187[2]
	II (8)	50	90	8,200	—	—	164[2]
	III (2)	50	80	7,060	—	—	141[2]
	IV (3)	50	70	5,910	—	—	118[2]
Douglas fir	I (13)	50	110	7,900	3,990	11,890	238
	II (32)	50	100	7,160	3,280	10,440	209
	III (15)	50	90	6,420	2,565	8,985	180
	IV (9)	50	80	5,740	2,065	7,805	156

Other conifers. Many other conifers are being tried for forest purposes in Britain, and of these three are worthy of special mention. One is *Abies grandis*, a plot of which at Novar in Scotland carried an under-bark volume, quarter girth, of 5,041 c.f. per acre at 26 years and showed a current annual increment of 437 c.f. This is probably the fastest growing coniferous plot in Europe. The species has given good results on peaty soil and may be found to be adapted to other difficult soils. The chief deterrent to growing it is the difficulty of obtaining supplies of seed.

Another species is *Thuja plicata* ('western red cedar'), a cypress from the west coast of America. This species is, by comparison, a slow grower, but its volume increment is higher than that of larch and it produces a timber with very special properties. It is at least as resistant to weather as larch and, as it grows very straight, it should be very useful for fencing and other outdoor purposes. The timber is also very light and is adapted to the making of ladders, gates, &c. In British Columbia, where it is extensively

1 From Hiley, *Oxford Forestry Memoir*, No. 6, 1926. 2 Without thinnings.

used for shingles and telegraph poles, the timber fetches a far higher price than Douglas fir. It thus appears that *Thuja plicata* might be used as a substitute for larch and, as it has a much better influence than larch on the soil it is growing on, it may be widely used. It will grow on clay, but probably not on very dry soils.

The Monterey Cypress (*Cupressus macrocarpa*) from California is a fast growing cypress which has been found to tolerate thin soils on chalk. Our experience with this tree is so far very limited and it is impossible to forecast financial results, but existing trials are encouraging.

Broad-leaved species. As there are no reliable yield tables for broad-leaved species in Britain, it is impossible to assess the average profitableness of such trees. The absence of yield tables is due to the lack of suitable stands for use as sample plots, and the same lack prevents our making reliable estimates of financial returns. The available evidence tends to show that there are very few areas in Britain which can be more profitably planted with hardwoods than with conifers, and the chief inducements to plant hardwoods arise from their ameliorative effect on soils, the protection which they afford to useful birds and their aesthetic value.

The oak (*Quercus pedunculata* and *Q. sessiliflora*) provides a timber with very valuable properties; it is also fairly easy to market as home timber merchants are accustomed to handling it. There are many reasons, however, why it cannot be considered a profitable tree. In order to give good results it requires close planting, though the early thinnings are of very little use; it is slow growing in youth and young plantations require attention for many years; it is slow in reaching maturity and long rotations are necessary. German estimates[1] suggest that in that country oak is slightly less profitable than Scots pine, and it is safe to regard the financial yields for Scots pine as being a fair indication of what might be obtained with oak. Land suitable for oak, however, will grow larch, Douglas fir, Sitka spruce, and other very profitable conifers, so that oak cultivation involves a definite sacrifice. It may be found possible to raise oak profitably if planted in mixture with other species, but methods of doing this are as yet experimental.

Beech (*Fagus sylvatica*) is faster growing than oak but its timber commands lower prices, and thinnings are only saleable under favourable conditions, as, for instance, where there is a demand for fire-wood or there is a local toy industry. The returns from beech

[1] See von Spiegel, *Praktische Waldwertrechnung*, Hannover, 1926, and p. 214 of this volume.

appear to be of the same order as those from oak. Beech may, however, be grown on chalk soils which are unfavourable to most species, and beech has a particular silvicultural value as a soil improver. It should be possible to regenerate this species naturally and thereby save much of the cost of initiation.

Ash (*Fraxinus excelsior*) is one of the most profitable broad-leaved species. Its timber has a higher value than any other kind grown in Britain, and it can be grown on comparatively short rotations of 50 to 70 years. It also regenerates itself freely. The silviculture of the tree presents difficulties as ash needs mixing with some denser crowned species and, owing to bud moth, a large percentage of the trees become forked. Ash grows best on a deep fertile loam, but heavier soils sometimes yield good results.

The black Italian poplar (*Populus serotina*) and other fast growing hybrids belonging to this genus demand different treatment from any other British trees, and may under suitable circumstances be very profitable. The special features of these poplars are: (1) though they prefer well drained soil they will grow on very wet ground which is unsuitable to most other species; (2) they are vegetatively propagated, so that special varieties can be segregated and rapidly increased; (3) they can be planted very widely: 12 ft. either way is a usual distance and still wider planting can be tolerated; (4) they are very fast growing, and a rotation of 30 to 40 years should give saw timber.

The trees are very intolerant of shade and will not stand keen competition; hence the volume produced per acre is not large, and the mean annual increment generally lies between 50 and 100 c.f. per acre.[1] The wood is useful for many purposes, including internal building work; it can be utilized extensively for crates and boxes, and if creosoted may be used out of doors.

It has been suggested that land may be planted very cheaply by placing poplar cuttings directly into holes made with a 'bushing iron',[2] and, as the plants may be 20 to 30 ft. apart, it may be simpler to wire each tree separately against rabbits than to fence the whole area. This treatment should be particularly suitable for areas of devastated hardwood on heavy soil such as frequently occur in the south of England. These areas are generally foul with scrub growth, and if planted in this way the scrub need only be cleared in

[1] See measurements given by W. H. Guillebaud, *Forestry Commission Bulletin*, No. 5, 1923.

[2] G. F. T. Leather, 'A cheap form of planting', *Quart. Journ. of Forestry*, vol. xxi, 1927, p. 22.

small patches for inserting the poplars. The separate wiring of each tree avoids the necessity of exterminating rabbits, and if the poplar grows it will soon be able to look after itself. Such a method should be suitable for small areas on estates which lack facilities for expert management and, while putting land which is otherwise waste to a fair use, it might prove to be fairly profitable.

The newer hybrids *P. regenerata* and *P. generosa* are very fast growing on fertile, permeable soils, and in northern France these trees reach timber size (about 5 ft. girth at breast height) in from 18 to 30 years.

Many other species, such as sweet chestnut, sycamore, alder, elm, hornbeam, &c., are planted in British woods, but there are no data on which any estimate of profitableness can be based.

Coppice or coppice with standards. This is a traditional form of woodland management in the south and midlands of England, and about 450,000 acres or 42·7 per cent. of the woodlands of this part of England is still classed as coppice or coppice with standards. This treatment produced a large amount of oak suitable for ship-building, fire-wood, tan bark, and materials for fencing, hurdles, barrel hoops, &c., besides fitting into the requirements of estate upkeep and forming admirable game coverts. In the last hundred years our national requirements have altered to such a degree that coppice and coppice with standards scarcely pay for the cost of upkeep. Only in exceptional cases are they still profitable.

The most remarkable exception to this rule is sweet chestnut coppice (*Castanea vesca*). Chestnut is too light-demanding to grow under standards, but great density can be maintained on the ground and a very large amount of material can be produced on a coppice rotation of 10 years. The prices obtainable for the crop have varied according to the demands of special markets, and records from the Cowdray estate in Sussex show two optimum periods for sale.[1] From 1860 to 1885 the poles were in great demand for hop fields, and prices exceeding £30 per acre were obtained; there was a gradual decline till 1900 to 1905 when only the best coppice could be sold. About 1905 a new industry, split chestnut fencing, was established, and in recent years prices of over £40 per acre have been realized for the best coppice at 8 to 9 years. It has been estimated[2] that a block of 1,000 acres of chestnut coppice, worked on a rotation of 12 years, can provide the equivalent of full-time work for from

[1] T. Roberts, *Quart. Journ.* of *Forestry*, 1929.

[2] W. L. Taylor, 'Chestnut coppice in S.E. England', *Forestry*, vol. ii, 1928, p. 81.

thirty to thirty-three men. The work, however, is regarded as seasonal and needs to be co-ordinated with other forms of employment.

Ash coppice also finds a ready sale in suitable areas owing to the use of small ash for handles, &c.

Mixtures. So far we have been dealing with the finance of growing species in pure stands; it is also necessary to consider the finance of species when grown in mixture. There are, however, no yield tables for mixtures of species, and the economics of mixed woods can only be treated on general grounds.

Mixtures are favoured by most silviculturists chiefly on the ground that they can be relied on better than pure stands to maintain or enhance the fertility of soils. This is an economic advantage also since the better the soil the faster will be the growth, and this will react favourably on financial returns so long as too large a space is not sacrificed to an economically inferior species. The classical example of such mixtures is oak and beech, and it has been claimed that an acre of oak and beech will produce more oak in a given time than the same area of oak grown pure. The example of larch and Douglas fir mentioned below is a parallel case.

Certain mixtures are attractive from an economic point of view without serving any silvicultural purpose. Thus larch may be mixed with oak or ash with the intention of removing it in the early thinnings; this serves a purpose since larch thinnings are more valuable than those of oak or ash, but it is not thought that the larch is silviculturally useful. As larch thinnings are more valuable than those of any other species there is a temptation to include larch in every mixture with the sole object of using it as thinnings, but, by doing this, the first principle of thinning is partly sacrificed, as much less scope is allowed for selecting the best stems for retention.

A mixture of this nature which is very successful in some places is larch with Douglas fir. In situations where the soil and climate are more favourable to larch than Douglas fir the former may keep pace with the latter for 20 to 25 years and, as larch yields the most valuable thinnings and Douglas fir a very large volume of saw timber, this mixture should prove to be one of the most profitable forms of forestry. Remarkable results have been obtained with sample plots of this mixture at Huntley in Gloucestershire[1] where at 16 years the mixture produced 858 c.f. of European larch and 1,064 c.f. of Douglas fir, whereas adjoining pure larch plots only

[1] C. P. Ackers, 'Sample plots at Huntley Manor, Glos.', *Quart. Journ. of Forestry*, vol. xix, 1925, p. 111.

produced an average of 841 c.f. Also the larch in the mixture was much straighter and cleaner than that in the pure woods.

The use of mixtures has been hindered by the difficulties which are often experienced in managing them in the pole stage. Species can only be satisfactorily mixed if their growth rates are fairly even or, at least, such that intolerant species can keep their crowns in the sunlight.

Uneven-aged mixtures, such as those produced by *underplanting* a light demander with a shade bearer are considered profitable by some foresters. The best-known instance of underplanting in Britain is at Novar in Scotland. On this estate about two hundred acres of European larch, which had been planted pure in 1883, became badly cankered and, when the trees were about 20 years old, the plantations were very heavily thinned, leaving about 350 trees to the acre, and underplanted in sections with various conifers. Of the younger crop some species, especially *Thuja plicata*, western hemlock, and Douglas fir, have grown extremely well, and the remaining larch have improved greatly in health and have become a valuable crop. There can be little doubt that in this case underplanting has been a success.

The economic objections to underplanting are: (*a*) it is expensive; if rabbits are present the area has to be wired so that the cost of underplanting is nearly as great as that of the original planting; (*b*) it is very difficult to remove the older crop without damaging the younger crop; it may therefore be necessary to grow them on till both can be marketed. This may necessitate too long a rotation for one crop and too short a rotation for the other. In areas where there is a good market for poles the younger stand may profitably be marketed in the pole stage, so that this difficulty may not arise. As compensation for these disadvantages it may be urged that, at any rate at Novar, the soil is improved by underplanting and the mean annual increment increased.

XIV

THE INFLUENCE ON PROFITABLENESS OF QUALITY OF SITE, DENSITY OF PLANTING, AND THINNING GRADE

Site quality: factors affecting site quality, climate, soil, aspect: price of land not proportional to value for forestry: figures from von Spiegel: methods of obtaining good land for forestry. Density of planting: controversy between silviculturists and economists: conditions under which close planting is profitable. The grade of thinning: economic value of heavy thinning: Engler's and Künanz's results: heavy thinnings lengthen the financial rotation.

Site quality. The quality of a forest site determines the species which may be grown, the ease with which they may be regenerated or plantations initiated, and the rate of growth of the trees.

Site quality is determined by soil, aspect, and climate. Of these the most important factor is climate, whether it is due to position on the earth's surface (compare the east and west coasts of Canada) or altitude. Under very dry or very cold climates tree growth is impossible, and rapid growth is only found under conditions of moderate to high temperature and rainfall and a long growing season.

In a restricted area such as Britain climate does not vary very greatly except in relation to altitude; but even in Britain growth in the west is more rapid than in the east. On the other hand, conditions which are favourable to tree growth are also favourable to weeds which make planting or natural regeneration more difficult, and for this reason less fertile situations have their compensations though they are seldom as profitable as more fertile sites.

Within definite climatic regions soil texture and quality are of great importance in determining the profitableness of forestry. A deep, fertile loam is adapted to the growth of almost any species and will allow of rapid growth; on such soils the most profitable species can be selected. Soils which deviate from this ideal in being either heavy, or light, or infertile allow of a more restricted range of species, and soils which are very heavy or very porous will often support only two or three kinds of tree. An example is provided by the light soils of the Bagshot sands and some other heath-bearing soils of Britain on which the choice of species is almost confined to Scots pine and Corsican pine and on which the quality class of these species is moderate or poor.

The influence of the quality class of the site on the financial

return from a species has already been demonstrated. For Scots pine the calculations referred to on p. 192 may be expressed in the following manner to show the relative value of sites of different quality classes. If the cost of planting is £7 per acre and of annual management 8*s.*, and if land costs £2 per acre, then the financial yield on 1st quality sites (with average present prices) is 2·9 per cent. on a 60–70 year rotation, on 2nd quality sites 2·3 per cent. on a 70–80 year rotation, and on 3rd quality sites 1·7 per cent. on a 90-year rotation. If land of Quality III could be obtained free of cost the financial yield would be 1·8 per cent., and this rate of interest might be earned on Quality II sites costing £12 or Quality I sites costing £25 per acre. From this it appears that timber could be raised more economically on Quality I sites costing £20 per acre than on Quality III sites costing nothing.

Comparative site values may also be computed from the tables given by von Spiegel[1] which are calculated from Schwappach's money yield tables. These yield tables comprise 5 quality classes for pine, spruce, and beech, and 3 for oak, and for each species the rate of interest (financial yield) which can be earned on Quality III plantations if the land costs nothing has been worked out and the price that can be paid for Quality II and Quality I land, so that the same rate of interest may be obtained has been calculated. The results of this calculation are given in Table XLVIII.

TABLE XLVIII. *Land values for different site qualities. Calculated from von Spiegel's data.*

Species.	*Financial yield.* %	*Price that can be paid for land to give financial yields, in mks. per ha.* *Quality* III	*Quality* II	*Quality* I
Scots pine	3·2	0	178	360
Spruce	3·8	0	150	362
Beech	3·4	0	36	179
Oak	2·6	0	77	826

In Britain the price of land has no direct relation to its forest quality since there is no competition to purchase land for forest purposes. The price, therefore, depends on its suitability for other uses such as agriculture, market gardening, building, and sport. Some land (e.g. many of the lower greensand soils in the south of England) has poor agricultural quality, but grows very good tree

[1] *Praktische Waldwertrechnung*, Hannover, 1926. Von Spiegel's results are quoted on p. 214 of this volume.

crops, and such land, being cheap, is the most profitable for planting. But the foregoing calculations, as well as the calculated costs of production of various species in Britain as given in Chapter XII, show that even where ordinary prices have to be paid for agricultural land it is more profitable to plant good land than poor, and timber can be raised more economically on good land.

Since under favourable circumstances agriculture yields a much greater value of produce per acre than forestry can hope to, it is undesirable that good agricultural land should be planted with trees. But there are other means of getting good land. In the south of England there is a large area of neglected woodland which has very little value at present. In order to make this 1st or 2nd quality forest land money must be spent on cleaning and draining, and such outlay increases the cost of land; but such land would still be more profitable to plant than less fertile bare land which costs nothing for preparation.

Again, there is the possibility of improving poor land, and considerable sums could economically be spent if the quality class of a site could thereby be raised. Owing, however, to the low rates of interest that are usually earned in forestry, landowners are often disinclined to spend more than is necessary on planting, though they may be prepared to make sufficient outlay to keep their land from becoming bare. In such cases it may be deemed necessary that any money spent on soil improvement should yield at least 5 per cent. interest, and it is possible to estimate how much money might be spent so as to yield this rate of interest if the site quality of land could thereby be improved. It has been shown on this basis that at least £11 per acre could wisely be spent in converting Quality I Scots pine land to Quality I larch land if the technique of doing this were known.[1] The technique of soil improvement for tree cultivation offers a very important field for experiment, and one of the most striking results of the study of forest economics is the discovery that large sums might profitably be invested in this manner if the practical measures were understood.

Density of planting. The question of planting distance is one which frequently arouses controversy between silviculturists and economists. Silviculturists generally favour close planting in order to secure canopy early and, thereby, kill out weeds and improve the soil, and also in order that branches may be early suppressed so that the timber may be free from large knots. If, however, trees are planted closely it is essential that early thinnings should be attended to, and,

[1] Hiley, *Oxford Forestry Memoir*, No. 6, 1926.

particularly with larch and Douglas fir, great density may cause whole plantations to be destroyed by wind or snow.

Wide spacing is favoured by economists because of the great saving in the cost of planting. The cultivation and purchase of plants and putting them in the ground generally costs between $\frac{1}{4}d$. and 1*d*. per tree. When transplants are used the average cost on private estates is about $\frac{3}{4}d$. per tree, but with seedlings it is considerably less. (This cost does not include fencing, cleaning land, or draining.) At this cost per tree the cost of plants and planting varies with spacing, as shown in Table XLIX.

TABLE XLIX. *The relation of cost of plants and planting, at $\frac{3}{4}d$. per tree, to spacing.*

Spacing.	*No. of plants per acre.*	*Cost of plants and planting per acre.*
3×3 ft.	4,840	£15·1
3½×3½ ft.	3,550	11·1
4×4 ft.	2,720	8·5
4½×4½ ft.	2,150	6·7
5×5 ft.	1,740	5·4
6×6 ft.	1,210	3·8
8×8 ft.	680	2·1

As this cost of planting is borne at the beginning of the rotation and is chargeable with compound interest there is clearly a great advantage in keeping it low, and any spacing which is closer than is useful is an unwarrantable extravagance. Nevertheless, in the case of larch and other species which give valuable early thinnings, close planting may be economically useful since the additional trees which are planted may themselves yield a profit. As the first thinnings are usually taken between 10 and 20 years from planting a doubling in the standing value of the earliest thinnings means a return in compound interest of from 7 to 3½ per cent., and with the better classes of larch and Douglas fir this return will be nearer 7 than 3½. At the same time allowance must be made for the early death of a part of the trees, and it may be taken as a general rule that it is profitable to plant so close that the earliest thinnings shall have a standing value of 2*d*. each.

Close planting is particularly to be advocated in areas where there is a good market for wireless poles, fencing stakes, rose poles, bean sticks, flower stakes, &c. In such areas Japanese larch may be planted at 3½ to 4 ft. with the intention of making a first thinning at

10 years, when the thinnings should be 15 to 20 ft. high. European larch could also be profitably planted at this distance, though Douglas fir might need to be rather more widely spaced.

The early thinnings of spruce are difficult to sell, except that Norway spruce may be sold for Christmas trees, and those of Scots and Corsican pine are usually valueless; indeed, the first thinning of pines is almost always a financial loss. These species should consequently be planted as widely as silvicultural demands allow. In this connexion there is a great deal of room for experiment in the pruning of side branches of conifers as soon as possible after they are dead. Pruning removes one of the disadvantages of wide spacing since, as soon as the branch ends are healed over, clear timber is formed by the boles of the trees; and by this means it should be possible to produce a better quality of Corsican pine timber than by close spacing without pruning. And, since the cost of pruning is incurred some years later in the rotation than planting, this cost would have less influence on profits than an equal amount spent in close planting. The data for such an investigation do not as yet exist, as the cost of pruning and its influence on timber quality have not been sufficiently studied.

Close planting is especially desirable on poor soils because it is necessary to obtain canopy as soon as possible, and where the young trees grow slowly canopy formation may be unduly delayed. On such soils, however, the early thinnings have seldom any value, for the more valuable species cannot be grown and, in any case, the first thinning must be much later on poor soils than on good, so that compound interest has to be paid over a longer period. On such soils it is particularly important to cut down the cost of planting to the lowest figure which is compatible with success.

The finance of forestry would be greatly benefited if crops could be discovered which might be interplanted with forest trees and, after helping to form canopy in the early years, would yield a useful product at 5 to 15 years after planting.

The grade of thinning. The manner of thinning stands has a very important influence on the financial returns obtained from them, and recent experience shows that heavy thinning is more profitable than light thinning. The advantages of heavy thinning are as follows:

(*a*) It is claimed by certain writers, particularly Bohdannecky and Gerhardt, that heavy thinning increases the growth both in height and volume. These claims apply particularly to spruce, and for this species Gerhardt[1] has published yield tables from which the figures

[1] *Allg. Forst- und Jagd-Zeitung*, civ, 1928, p. 377.

in Table L are taken. Schwappach[1] and Engler have been unable to confirm the high volume yields claimed by these writers, but they agree that, owing to greater diameter increment, heavy thinnings hasten the increase in value.

TABLE L. *Relation of height growth and volume increment to thinning grades. Norway spruce, after Gerhardt.*

	Moderate thinning		*Heavy thinning*		*Very heavy thinning*	
	Hgt. m.	*Mean ann. vol. incr. m³ per ha.*	*Hgt. m.*	*Mean ann. vol. incr. m³ per ha.*	*Hgt. m.*	*Mean ann. vol. incr. m³ per ha.*
Quality I (80 yr.) . .	30·2	14·4	31·7	15·6	33·1	16·8
Quality II (90 yr.) . .	27·7	11·1	29·0	11·9	30·4	12·7
Quality III (100 yr.) . .	25·1	8·2	26·1	8·8	27·2	9·4

(*b*) Even if the volume increment is not materially increased, heavy thinning reduces the number of trees per acre, so that the increment of individual trees is more rapid and diameter increment is greater. Thus the trees reach timber size more quickly and the value of the annual increment is greater. We must set against this advantage that when trees are grown further apart the annual rings are broader and the timber is generally more knotty; consequently the best quality timber is likely to be produced in more lightly thinned stands. The size increment, however, more than compensates for this slight deterioration in quality.

(*c*) With heavy thinning a larger value is removed in the form of intermediate yields and the capital value of the remaining stand is lessened. Since this lower capital value yields a greater value increment the rate of interest which income represents on capital is much higher.

Calculations to show the influence of heavy thinnings on forest finance have been made by Engler, Künanz, and others. Engler's figures[2] relate to actual sample plots in the Sihlwald and elsewhere in Switzerland where comparative thinnings of grades A to D have been carried out, D grade being the heaviest thinning (all 'stem thinnings'). Crown thinning (H) was introduced later into the experiments. Engler compared the growth in value of the stands under different grades of thinning by means of the indicating per cent. (p. 159). He used Kraft's formula

$$1{\cdot}0w^n = \frac{Y_{x+n} + T_a \,.\, 1{\cdot}0p^{x+n-a} + \ldots + T_c \,.\, 1{\cdot}0p^{x+n-c}}{Y_x} - \frac{S+E}{Y_x}(1{\cdot}0p^n - 1)$$

[1] *Allg. Forst- und Jagd-Zeitung*, c, 1924, p. 79.

[2] *Mitt. d. schweiz. Central. f. d. forstl. Versuchsw.*, xiii, 1924, p. 285.

where Y_x and Y_{x+n} are the values of the main crop at the years x and $x+n$, T_a, &c., the value of intermediate thinnings, S the value of land, E the capitalized value of the cost of annual maintenance $\left(\frac{e}{\cdot 0p}\right)$, p some arbitrary rate of interest (the forest per cent.), and w the indicating per cent. or current annual forest per cent. It is to be regretted that two rates of interest have been used in these calculations, viz. a fixed rate, in this case 3 per cent., on the value of the land and cost of management as well as the sums received for thinnings from the time they were taken to the end of the experimental period, and an unknown rate, w (to be calculated), on the value of the growing stock; but this method simplifies calculations.

TABLE LI. *Financial results of different grades of thinnings. (Engler.)*

Year.	*Age. yrs.*	*A* %	*B* %	*C* %	*D* %	*H* %
		Sihlwald. Spruce: Quality I.				
		Indicating per cent. for thinning grades.				
1889–99 . .	28–38	2·58	3·12	3·72	4·62	—
1899–1911 . .	38–50	2·40	2·64	3·21	3·79	—
1911–21 . .	50–60	3·17	3·67	3·73	4·50	—
		Olten. Spruce: Quality III.				
1888–1899 . .	22–33	—	5·30	7·50	8·18	—
1899–1913 . .	33–47	—	5·91	6·00	6·92	6·16
1913–1921 . .	47–54	—	5·28	5·63	6·46	5·92
		Aarburg. Beech: Quality II.				
1889–1902 . .	36–49	—	4·57	4·95	—	—
1902–1913 . .	49–60	—	2·14	2·17	—	—
1913–1921 . .	60–68	—	3·82	3·98	—	3·87
		Concise. Beech: Quality IV.				
1889–1901 . .	29–41	5·60	6·60	8·25	—	—
1901–1908 . .	41–48	6·35	5·66	4·52	—	—
1908–1916 . .	48–56	2·78	4·31	3·84	—	3·35

From these results it appears that heavy thinning is far more profitable than light thinning in the case of spruce. It is also more profitable with beech, though the difference is much less marked.

Künanz[1] based his calculations on yield tables, partly taken direct from others and partly compiled from isolated experimental results

[1] *Forstl. Centralbl.*, 1924, pp. 183, 237.

of heavy thinnings. Table LII shows the financial rotation and the gross soil expectation value[1] under B and C grade thinnings, calculations being made at 3 per cent. interest.

TABLE LII. *Financial rotation and gross soil expectation value under* B *and* C *grade thinnings (Künanz).*

	B. Grade.		C. Grade.	
	Financial rotation.	S_e+E	*Financial rotation.*	S_e+E
	yrs.	*mks. per ha.*	*yrs.*	*mks. per ha.*
Spruce, II . .	60	1,501 (1,001)	80	1,648 (1,148)
Pine, II . .	60	635 (235)	90	880 (480)
Beech, I . .	70	814 (514)	110	973 (673)
Oak, I . .	90	870 (370)	140	1,419 (919)

Taking the cost of annual management per ha. for these crops at 15, 12, 9, and 15 marks respectively,[2] the capitalized values $\left(E \text{ or } \frac{e}{\cdot 0p}\right)$ may be put at 500, 400, 300, and 500 marks. Deducting these amounts from S_e+E the values of S_e (the expectation value of the soil) which have been entered in brackets are obtained. These results show that with heavy thinnings not only are the profits greater but the financial rotations are longer. It should be noted, however, that these financial rotations are calculated by the method of soil expectation value at 3 per cent. From Künanz's oak data for C grade thinning it has been calculated that at $3\frac{1}{2}$ per cent. the financial rotation is 110 years and the gross soil expectation value 900 marks, which is equivalent to a net soil expectation value of $900-430 = 470$ marks. Thus on land worth about 400 marks per ha. which produces Quality I oak, B grade thinning gives a financial yield of just under 3 per cent. on a 90-year rotation, and C grade gives a financial yield of just over $3\frac{1}{2}$ per cent. on 110-year rotation.

[1] The gross soil expectation value $= S_e + E$ where $E = \frac{e}{\cdot 0p}$. The Faustmann formula may be written

$$S_e+E = \frac{Y_r + \Sigma T_a \,.\, 1{\cdot}0p^{r-a} - C \,.\, 1{\cdot}0p^r}{1{\cdot}0p^r - 1}.$$

[2] Figures quoted from von Spiegel, *Praktische Waldwertrechnung*. Hannover, 1926.

XV

THE FINANCIAL ROTATION

Methods of determining the financial rotation: (1) financial yield: (2) method of simple interest, or interest on realizable capital: von Spiegel's calculations for pine, spruce, beech, and oak in Germany: (3) the methods of soil expectation value and soil rental: financial rotation varies according to rate of interest applied: calculations for Douglas fir for America: (4) method of indicating per cent.: used chiefly in unregulated forest: Kirkland's application in America: (5) method of forest rental. Should financial rotations be adopted? Reasons for the long rotations which are at present practised in Germany and elsewhere: gradual shortening of rotations may be expected.

Methods of determining the financial rotation. By *rotation* is meant the average period between the planting of a stand, or its establishment by natural regeneration, and the felling of the final crop. The idea of rotation is based on the management of even-aged stands. In selection forest there need be no predetermined rotation, though the rotation may here be assessed as the average age at which the timber trees are felled.

In practice there is no need to predetermine a rotation to any greater precision than the nearest decade. The condition of markets, the position of the work on an estate, and other considerations are likely to reduce or prolong it, so that predetermined plans should be as elastic as is compatible with efficient management.

The factors which influence a forester, in so far as he is independent of tradition, in determining the length of rotation on which any species is to be grown are economic, silvicultural, and technical. If his outlook is industrial his choice will be most strongly affected by economic considerations, and he will work to the financial rotation.

Though it is accepted that the financial rotation is the rotation which is most profitable, there is no agreed criterion of profit by which the financial rotation may be determined. And, as different methods of estimating the financial rotation give different results, the more important of them will be briefly discussed.

1. Financial yield. By this method the financial rotation is that rotation which gives the highest financial yield or mean annual forest per cent. (see pp. 134 ff). In other words, it is the rotation by which the highest rate of interest may be earned on money invested in buying the land, planting or regenerating, and upkeep.

This method is only applicable to regulated forests in which sums

can be estimated for each item of expenditure and income. It is based on calculations for the unit stand with discontinuous working, but it may be used equally well for a whole forest which gives a sustained annual yield by summing up the returns from the individual stands.

The rotation of highest financial yield frequently appears to be very short. As shown in Table XXXVII, p. 173, for Scots pine, Quality II, using Schwappach's money yield table, the rotation of highest financial yield is only 40 years, a rotation on which saw timber can scarcely be produced. It is probable that, if all the state pine forests in Prussia were worked on this rotation, the market for pit-timber would be swamped and the price of the kind of wood which can be grown on a 40-year rotation would fall heavily. It would then be necessary to construct a new money yield table and to recalculate the financial rotation, which would then be found to be longer than 40 years. It is therefore clear that the financial rotation calculated on existing prices cannot always be made a basis for management. The high price which is now obtainable in Prussian forests for small timber must be ascribed to the long rotation on which the state forests are actually worked, since long rotations create a shortage of small sizes.

In the state forests of Prussia pine is to-day managed on a rotation of about 120 years; but under the new regulations introduced by Trebeljahr this is to be reduced gradually to 100 years. It is probable that a still shorter rotation could be adopted without greatly upsetting the market, but it is clearly a wise course to proceed with caution. It is worthy of note that in south Finland, where pine does not grow any faster than in Prussia, the average rotation is about 80 years.

In the case of European larch, Quality II, in parts of Britain where the market for thinnings is poor and the prices of timber agree with the data on p. 127, the highest financial yield is obtained, on land costing £5 per acre, with a rotation of just over 40 years. In this case, too, it is doubtful how large an area could be satisfactorily managed on such a short rotation. The final crop would find its market in telegraph poles, scaffolding poles, pit props, &c., though a certain number of the trees would be large enough for the saw bench.

2. The method of simple interest or interest on realizable capital. This method is applied most easily to a forest worked on a system of sustained yield. Calculations may be based on a money yield table, as has been done in Chapter IX, when it is found that

the rate of interest on realizable capital culminates at the same rotation as the financial yield. Also the rate of interest is then equal to the financial yield, but for longer rotations it is less.

Von Spiegel[1] has calculated the rate of interest on realizable capital earned by forests of pine, spruce, beech, and oak from Schwappach's money yield tables. In these calculations he adopted, as cost of planting per hectare, 80 mks. for beech, 160 mks. for pine, 240 mks. for oak, and 320 mks. for spruce (figures based on Prussian costs in the years 1903 to 1912), and as annual costs of management per hectare the figures shown in Table LIII. The price of land has been estimated partly from actual purchases and partly from calculated soil expectation values; the figures adopted are shown in Table LIV.

TABLE LIII. *Cost of annual management in mks. per ha.*

Quality class.	I	II	III	IV	V
Pine .	. 14	12	11	10	8
Spruce	. 16	15	14	12	10
Beech	. 9	8	7	6	5
Oak .	. 15	13	10	—	—

TABLE LIV. *Cost of land in mks. per ha.*

Quality class.	I	II	III	IV	V
Pine .	. 600	430	320	210	120
Spruce	. 700	500	340	220	120
Beech	. 870	650	460	290	150
Oak .	. 770	420	250	—	—

Von Spiegel further corrected Schwappach's money yield tables for the change in prices from 1908 to 1912, and for the average efficiency. Thus pine prices had risen 10 per cent., but von Spiegel estimated that the average volume yield was only 80 per cent. of Schwappach's yield table estimate. He therefore reduced Schwappach's money yields by 10 per cent. He reduced spruce money yields by 30 per cent., beech by 10 to 20 per cent., and oak by 30 per cent.

The rates of interest earned on realizable capital, as calculated by von Spiegel, are shown in Table LV. It will be seen from this table that the financial rotations for conifers, and particularly for pine, are very much lower than the rotations normally adopted. In the case of pine they are lower than can be considered reasonable.

3. METHODS OF SOIL EXPECTATION VALUE AND SOIL RENTAL. In these methods a fixed rate of compound interest is employed in the calculations. As more fully described on p. 152 the expectation value of the land is calculated as the discounted value of all income less the discounted value of all costs except land. It is the amount which

[1] *Praktische Waldwertrechnung.* Hannover, 1926.

can be paid for land if the rate of interest, with which calculations are made, is to be earned on the capital invested in the plantations.

TABLE LV. *Rates of interest on realizable capital as calculated by von Spiegel.*

Rotation years.	*Quality* I	*Quality* II	*Quality* III	*Quality* IV	*Quality* V
			Pine.		
40	2·71	2·36	—	—	—
50	**2·78**	**2·60**	**2·31**	1·64	—
60	2·69	2·55	**2·31**	1·81	1·20
70	2·66	2·40	2·21	**1·85**	1·53
80	2·53	2·33	2·06	1·83	**1·59**
90	2·36	2·24	2·01	1·79	1·56
100	2·19	2·13	1·97	1·73	1·52
110	2·11	2·08	1·90	1·70	1·42
120	2·02	2·00	1·78	1·65	1·32
130	1·93	1·88	1·68	1·56	—
140	1·77	1·71	1·58	—	—
			Spruce.		
50	2·98	—	—	—	—
60	**3·38**	2·88	2·57	1·68	—
70	3·28	**3·27**	**2·99**	2·46	1·33
80	3·10	3·13	2·98	**2·73**	1·99
90	2·88	2·88	2·83	2·67	2·20
100	2·63	2·66	2·62	2·55	**2·26**
110	2·43	2·46	2·40	2·39	2·10
120	2·24	2·26	2·22	2·20	—
			Beech.		
60	1·80	1·44	—	—	—
70	2·10	1·79	1·55	—	—
80	2·22	2·05	1·90	1·56	—
90	**2·25**	2·17	2·10	1·85	1·32
100	2·24	2·24	2·17	2·03	1·57
110	2·21	**2·26**	**2·20**	**2·10**	1·76
120	2·18	2·24	2·19	2·09	**1·77**
130	2·15	2·18	2·15	2·06	1·74
140	2·09	2·03	2·08	—	—
			Oak.		
80	2·33	1·50	1·23	—	—
90	2·47	1·76	1·50	—	—
100	2·61	1·94	1·76	—	—
110	**2·64**	2·06	1·96	—	—
120	2·61	2·10	2·06	—	—
130	2·51	**2·17**	**2·07**	—	—
140	2·32	2·16	1·95	—	—

Rotation years.	*Quality* I	*Quality* II	*Quality* III	*Quality* IV	*Quality* V
		Oak (cont.).			
150	2·13	2·06	1·84	—	—
160	1·95	1·91	1·69	—	—
170	1·80	1·76	1·56	—	—
180	1·67	1·62	1·43	—	—
190	1·54	1·48	1·32	—	—
200	1·43	1·35	1·22	—	—

(*Note.*—Though they are derived from the same money yield table, von Spiegel's results for pine, Quality II, are very different from mine (p. 173). This difference arises partly from a different method of estimating the value of immature stands and partly from taking different figures for cost of planting, cost of management, and price of land i.e. 160, 12 and 430 mks. in place of 80, 6 and 100 mks.)

By the method of the soil expectation value, the financial rotation is that rotation by which the calculated soil expectation value is highest. But it will be found that the financial rotation, calculated in this way, is affected by the rate of interest at which the calculations are made and will be longer at a low than at a high rate of interest. This is graphically demonstrated in an indicator graph, such as is reproduced in Fig. 14, p. 144. For a study of the method of working will show that the curve representing 2 per cent. in this graph is actually the curve of soil expectation values calculated at 2 per cent. for various rotations. From the graph it will be seen that at 2 per cent. the soil expectation value culminates at 64 years, at 3 per cent. at 50 years, at 4 per cent. at 43 years, and at 5 per cent. at 40 years. Similarly from the indicator graph on p. 167 it can be shown that for Scots pine, Quality II, if calculations are made at 2 per cent. the soil expectation value culminates at 70 to 80 years, at 3 per cent. it culminates at 50 to 60 years, at 4 per cent. at about 45 years, and at 5 per cent. at 40 years.

Table LVI, which shows the soil expectation values for larch,

TABLE LVI. *Soil expectation values for European larch, Quality III (after Schlich).*

Rotation years.	*Soil expectation value in shillings when calculated at* 3%	$3\frac{1}{2}$%	4%	$4\frac{1}{2}$%
30 . .	157	90	41	5
40 . .	312	197	115	**55**
50 . .	365	**216**	**122**	52
60 . .	374	214	106	31
70 . .	**385**	209	92	10
80 . .	364	183	66	—12

Quality III, as calculated by Schlich,[1] shows the same relationship. Therefore, in order to calculate a financial rotation by means of the soil expectation value, or forest rental, method, it is first necessary to decide on a rate of interest at which the calculation is to be made. The fairest way of meeting this difficulty is to use a rate of interest by which the calculated soil expectation value shall be approximately equal to the market-price of the land. But the rate of interest which makes the soil expectation value equal to the cost price of the land is itself the financial yield, and the financial rotation calculated by this method will be the same as that calculated by the method of financial yield. This point is illustrated by the following example.

Hanzlik[2] calculated that under certain circumstances in the Western Cascades the financial rotation for Douglas fir, Quality II, was 70 years, since the soil expectation value at 3 per cent. interest culminated at that rotation. This result was computed from a money yield table constructed from the standard volume yield table for Douglas fir; the final yields were reduced by 35 per cent. to cover taxes; the cost of formation was taken as nil and the annual cost of management was estimated at $0·20.

The soil expectation values have been recalculated with rates of interest of 3, 4, 5, 6, and 7 per cent. and the results are shown in Table LVII. The newly calculated values at 3 per cent. interest are slightly different from Hanzlik's, and with these new values the financial rotation appears to be 80, not 70 years.

TABLE LVII. *Douglas fir, Quality II. Soil expectation values calculated from Hanzlik's money yield table.*

Rotation years.	*Thinning.*	*Final yield less 35%*	3%	4%	5%	6%	7%
	$	$	$	$	$	$	$
30	1·90	26·30	11·7	6·7	3·9	2·1	1·1
40	9·80	39·00	11·7	6·0	3·0	1·2	0·2
50	15·00	84·80	23·3	11·9	6·1	2·9	1·1
60	13·80	166·00	36·0	17·7	**8·7**	**4·0**	**1·5**
70	18·90	242·00	39·3	**18·1**	8·2	3·4	0·9
80	14·60	325·00	**40·2**	17·3	7·3	2·6	0·4
90	14·40	415·00	38·8	15·7	6·0	1·9	0·0
100	—	515·00	36·6	13·9	5·0	1·1	—0·3

These figures show that if calculations are made at 3 per cent. the financial rotation appears to be 80 years, at 4 per cent. 70 years, and at higher rates of interest 60 years. Unless we know which rate

[1] *Manual of Forestry*, vol. iii, 5th ed., 1925, p. 154.

[2] Quoted by Woolsey, *American Forest Regulation*, 1922, pp. 50–1.

of interest to adopt the financial rotation is indeterminate. If, however, the market value of the land is not more than $1½ per acre, 7 per cent. compound interest can be realized on the capital invested in regenerating and maintaining these forests, but in order to do this the rotation must not be longer than 60 years. In other words, if the value of the land is known the financial rotation can be determined as that rotation which gives the highest financial yield (in this case 7 per cent.), and the prolongation of the rotation to 80 years would not be financially justified unless the market price of the forest land immediately after felling were $40 per acre.

4. Method of indicating per cent. The principle of this method is that stands should be cut as soon as their annual increase in value, less the annual cost of upkeep, represents less than a certain rate of interest on the capital value of land and crop. This rate of interest is the indicating per cent. or current annual forest per cent., and, as shown in Fig. 15 (p. 163), the indicating per cent. reaches a maximum very early in the life of a stand and then falls off gradually. Therefore the lower the rate of interest accepted as a satisfactory indicating per cent. the longer will be the rotation; and it is by no means easy to agree on an indicating per cent. which may be accepted as a satisfactory minimum.

Fig. 15 shows that at rotations lower than the financial rotation (i.e. the rotation which gives the highest financial yield) the indicating per cent. is higher than the financial yield, and at rotations longer than the financial rotation the indicating per cent. is lower than the financial yield. Thus, in order to obtain the highest financial yield the indicating per cent. must be chosen equal to the financial yield at the financial rotation, and, for this reason, indicating per cent. calculations have no value in determining the financial rotation. This statement, however, only applies to forests for which yield tables are available and the costs of initiation and maintenance are known.

The method of the indicating per cent. has a very definite use in the control of unregulated forest, particularly in regions, such as the west coast of America, where the price of standing timber is rising rapidly. For such forests Kirkland[1] advocates a scheme of management which is based on the indicating per cent. calculated with regard to growth in volume, quality, and price. He suggests dividing a forest area into compartments for which the volume, increment, and standing value can be estimated. He gives an example in which

[1] B. P. Kirkland, 'Flexible rotation in American Forest Management', *Journal of Forestry*, vol. xxiii, 1925, p. 136.

the present standing prices range from nothing to $4·00 per thousand b.f. according to size and position, and he presupposes that prices will rise by $2·00 per thousand b.f. during the next ten years. Those compartments which already contain mature timber in easily accessible positions will grow least in volume and the increment in price will represent the smallest percentage on their present standing value. Compartments, on the other hand, which contain small timber in inaccessible parts of the forest are likely to provide much more volume increment, and as their present standing value is very low a rise of $2·00 per thousand b.f. will represent a very large percentage on their present value. In the example given the indicating per cent. for the various compartments ranges from 3·4 to 20·6 per cent., and utilization should begin with those compartments yielding the lowest indicating per cent., whereas those compartments which yield a high indicating per cent. can more profitably be left standing.

5. The forest rental. As has been shown in Chapter XI the rotation of highest forest rental, or highest net annual income, has no special economic attractiveness, and to call this the financial rotation is a misnomer.

Should financial rotations be adopted? From the time when Pressler began to make specific calculations on forest finance it has been realized that organized forests, particularly state forests, are mostly worked on rotations which are considerably longer than the financial rotations. This may be accounted for by several reasons, of which the following are probably the most important.

(*a*) Sawmill traditions have been founded on the conversion of large timber from virgin, or little used, forests. Until the introduction of iron, steel, and concrete for building there was a large demand for large-sized lumber, and sawmillers were unwilling to buy lots of standing timber which did not contain the requisite proportion of large-sized logs. Also, the conversion of small timber involves much more wastage than that of large timber. Despite the reduced demand for large sizes of sawn timber this tradition has been maintained.

In Finland, where the sawmilling industry is a recent development, this tradition has had less influence than in Germany and France, and Finland has built up its very extensive lumber export on small-sized timber. The average tree cut in the state forests is only 13 c.f. (17 c.f. true measure) in volume.

In America the timber trade has been served by the enormous quantities of large trees which were present in the virgin forests,

and the economic conversion of small timber is little understood. American forest economists are now endeavouring to educate the sawmillers in the use of small sizes.

(*b*) The reputation of foresters is chiefly based on the appearance of the forests for which they have been responsible. Forests worked on a long rotation contain more timber and larger trees than forests worked on a short rotation, and consequently have a better general appearance.

(*c*) If a forest worked on a short rotation is compared with a similarly situated forest worked on a long rotation it will be found that in the former a lower price per unit measure for standing timber is received and a lower net income per acre is obtained. This lower income may be fully justified by the fact that the former forest is worked on much less capital than the latter, but this difference is often disregarded by superficially minded critics, and the manager of the former forest receives less credit than the manager of the forest worked on a long rotation. A forester who is prepared to lower the rotation in his forests may make heavy inroads into his capital and thereby increase the apparent income; but by doing this he would become subject to the criticism of most of his fellow foresters and his credit would be likely to suffer.

(*d*) It is generally recognized that large timber costs more per unit measure to produce than small timber, but it is not often realized how rapidly the cost of production rises with an increase in the size of tree. It is shown in Chapter XII, which deals with the cost of production of timber, that on Quality II sites, if 4 per cent. is charged to capital, the cost per cubic foot of producing Scots pine of 10 c.f. is 1*s.* 6·3*d.* while the cost rises to 2*s.* 4·4*d.* for trees of 20 c.f. and 3*s.* 8*d.* for trees of 30 c.f. These three prices are proportional to 100 to 154 to 240. With Douglas fir, on the other hand, the corresponding prices are 5·7*d.*, 6·5*d.*, and 7·1*d.*, which are proportional to 100 to 114 to 125. Whether or not it pays to grow large sizes will depend on whether the price increment for increased size corresponds to the cost increment, and it appears from the above figures that with some species it may pay to grow large sizes, whereas with others it does not. For instance, it may be worth while to grow large Douglas fir, but not to grow large Scots pine. In general it will be found profitable to grow those species which yield a high increment per acre to a larger size than those which yield a low increment.

The enormously high cost of production of large timber is due to the incidence of compound interest, and in order to get over this difficulty many foresters have questioned the reality of compound

interest. If, however, the finance of forestry is expressed in terms of a normal forest and the income is calculated as earning a rate of simple interest on the realizable capital in the forest (see pp. 172, 173) a similar result is obtained. From Table XXXVII, p. 172, it will be seen that on a rotation of 40 years income represents a rate of 4·44 per cent. on capital, whereas on a rotation of 100 years income represents a rate of 3·06 per cent. on capital. At first sight it appears that if the price of timber cropped on a rotation of 100 years is raised by 50 per cent., then a 100-year rotation will give as high a rate of interest on capital as a 40-year rotation; but this is not so, for if the price of large timber is raised the capital value of a normal forest worked on a 100-year rotation will also be increased. In order that income on a normal forest worked on a rotation of 100 years shall represent 4·44 per cent. on the capital value the price of timber cropped at 100 years must be raised by considerably more than 50 per cent.

(*e*) The claims made by forest economists that rotations in most of the German state forests should be shortened has given rise to a prolonged controversy which is often referred to as the controversy between the soil rental and forest rental schools. As the soil rental method is scarcely used in this book, and, as the forest rental theory has been shown to be financially fallacious, these terms have very little significance in the present discussion. The controversy, however, continues as a dispute between those who wish to keep a large amount of capital in the forest and those who wish to reduce the capital. The former favour long rotations and the latter short rotations. The arguments advanced by the forest rental school must therefore be considered.[1]

These arguments may be divided into two classes. The first is the social argument that land should be made to produce as high a value of timber as possible, despite the fact that the rotation of highest income is a very long one and less financially attractive than a shorter rotation. This argument is especially applied to countries which do not produce as much timber as they use and consequently have to import timber of a nature which they might grow. In opposition to this view it has been claimed that if timber can be imported more cheaply than it can be grown, it is better to import. In Great Britain, however, where forest policy is based on the necessity for assuring internal supplies of timber during a war or other period when imports might be cut off, this argument may have considerable weight.

[1] For a review of the literature of this subject see Hiley, 'A critical note on some recent literature on forest economics', *Forestry*, vol. i, 1928, p. 97.

The second class of argument is silvicultural in character. It is claimed that with long rotations the quality of the soil is maintained or improved far better than with short rotations. The falling off in soil quality which has occurred during recent years in Saxony is attributed to the application of short rotations under the guidance of Pressler and Judeich. Wiedemann, Trebeljahr, and others have contested this view, and the matter is too complex to allow of any ready solution, but there is little doubt that if silviculturists directed their skill towards maintaining soil fertility under systems of comparatively short rotations, realizing that the greater profitableness of short rotations allows money to be spent for this object, then no insuperable difficulties would be found. Trebeljahr[1] asserts most emphatically that soils in the Prussian pine forests have been definitely harmed by too long a rotation and claims that soil improvement would result from a shortening of the rotation.

The length of the financial rotation is greatly affected by the relative prices for various sizes of timber; where there is a good market for small sizes the financial rotation will be short and where there is a poor market for such sizes the financial rotation will be long. In timber importing countries the price of large timber is to a great extent determined by the world supply and demand, but small sizes of timber do not pay for expensive transport, and the price of these may be largely determined by local supply. Any change in the local supply may affect the price of such small sizes, and this fact has to be taken into account when a change in rotation over a large area of forest is considered.

An example of this is provided by the Prussian pine forests which have been worked on an average rotation of about 120 years, a rotation by which a large amount of big timber and a relatively small amount of small timber is produced. For this reason the price of small timber is high, which makes the calculated financial rotation very short (about 40 years). If, however, the average rotation in Prussia were reduced to 80 years the supply of small timber would be greatly increased and it is probable that the price would fall. A new size-price gradient (see p. 124) would then be produced, and the financial rotation calculated on this gradient would be longer than 40 years. It might be 70 years. Thus where the rotation in practice is very different from the financial rotation, any shortening of the rotation must be adopted tentatively.

During the last few decades changes in industrial usage have increased the demand for small timber at the expense of big timber.

[1] 'Rationelle Forstwirtschaft', *Allg. Forst- u. Jagd-Zeit.*, 1924, p. 166.

Not only have iron, steel, and concrete to a great extent replaced large timber in building construction but, by means of plywood and spliced wood, large sizes are actually being manufactured from small trees. Conversion to pulp is also more profitable from small trees than large. It is, therefore, not surprising that the prices for small timber should be rising more rapidly than the prices for large timber, as is shown by the price movements in Germany quoted on p. 86.

Forest practice may be expected gradually to adapt itself to the changing conditions of the timber market, and one result of such adaptation is likely to be a general shortening of rotations.

XVI

THE ECONOMICS OF SUSTAINED YIELD

Forest management and devastation: sustained yield. Devastation value and management value of a forest: normal forest: overmature virgin forest: intermediate types. The conflict between public good and private gain. State control of forests: state ownership: legislation to control privately owned forests: state controlled companies. Forest management under private ownership. Company forest management: factors which encourage companies to introduce forest management. Rate of profit is a controlling factor.

Forest management and devastation. The fundamental conception of forestry, as opposed to lumbering, is the principle of *sustained yield*. This principle need not be interpreted in any narrow or restricted sense, and it may be permissible, or even desirable, to cut in any one year, or in a series of years, more timber than is grown in that space of time; areas in which the timber is over-mature or which for other reasons are unproductive may justifiably be felled in the shortest convenient time in order that the land may be made to yield a higher increment; or a period of good markets may be exploited by means of heavy fellings. What the principle of sustained yield does demand is that after timber is felled the forest shall by some means be regenerated so that a fresh crop of trees is initiated and the land continues to produce useful timber. So long as this principle is followed a forest may be said to be undergoing *forest management*.

The antithesis to forest management is *devastation*. Under a system of devastation the object of the forest lumberer is to exploit the capital value of a forest without regard to the future of the land and without the adoption of precautions which are necessary to secure a further crop. It may happen that in spite of no such precautions having been taken a new crop may arise, and most of the 'second growth' which is now being utilized in eastern and southern U.S.A. has come by chance rather than design. But no system can be justifiably termed forest management which does not involve the conscious and intelligent adoption of methods which will secure this end. Devastation may be rapid, as when forest areas are clear-felled, or it may be gradual, as when only the most valuable species are removed or when the best trees are taken a few at a time. Such fellings only cease to be devastation when they are accompanied by measures which secure the regeneration of useful species.

From a good deal of the literature of forest policy it would appear

that the advantages of forest management over devastation are such that they have only to be stated for any intelligent forest owner to be convinced; and it is often thought that lack of technical ability and interest are the only real deterrents to the universal adoption of forest management. This, however, is far from being the case. A lumbering company which has the best possible intentions with regard to forest management may be faced by very real difficulties which it is the duty of forest science to study and remove.

The first of these difficulties is the lack of silvicultural knowledge. Methods of regenerating many valuable species are at present unknown, and until this ignorance has been overcome forest management can never be effective. This applies to many of the virgin forests of the world, particularly in the tropics, and in such cases silvicultural research is a necessary precedent to forest management. The second difficulty is that, even when silvicultural methods have been discovered, forest management may entail a financial sacrifice on the part of a forest owner. It is this financial sacrifice which the present chapter attempts to elucidate; it should be the object of forest economics to convert this sacrifice into a financial gain.

Devastation value and management value of a forest. The devastation value of a forest is the standing value of the timber in it plus the value of the land, if this has any value after the timber is felled. This simple definition may require modification in particular cases; the forest may be too big to fell in one year, and since the value of a sum of money realized from felling five years hence is not equal to the same sum realized to-day, a part of the value may have to be discounted for the number of years which will elapse before felling; taxes may have to be deducted; the standing value may be greatly increased by improvements in transport facilities, and consequently the value may be largely speculative. Also immature timber may have a future, or expectation, value which is greater than its utilizable value to-day. Such qualifications have to be admitted for particular cases but do not affect the conception of devastation value.

The management value is the value which the forest represents to an owner who introduces or maintains a system of sustained yield. When such a system is adopted the amount that can be immediately realized from the forest is less, for, even if the whole area is cut at once, a part of the money obtained from felling must be reinvested in regeneration and protection of the forest. In general, however, under a system of forest management the whole area is cut gradually, over a period which corresponds to the intended rotation, and consequently the value to the owner must be expressed

in terms of an income or annuity. The management value is partly or wholly the capitalization value of an income and, as such, involves a rate of discount.

The devastation value and management value are most easily compared in the case of an ideally normal forest, e.g. a forest of r acres which contains one acre of each age 1 to r years. In such a forest the annual net income, I, is represented by the formula[1]

$$I = Y_r + \Sigma T_a - C - re,$$

and the management value of the forest, M, is given by the formula

$$M = \frac{I}{p} \times 100, \text{ or } M = \frac{I}{0{\cdot}0p},$$

where p is the rate of discount.

The devastation value, D, of such a forest is given by the formula

$$D = Y_r + Y_{r-1} + Y_{r-2} + \ldots + Y_1 + rS.$$

(In this formula Y_1, Y_2, &c., will represent the yields from stands which are too young to cut and which only have an expectation value. The determination of this expectation value will involve a rate of discount, but if the rotation is fairly long such values may be ignored as they form a very small part of the total value of D.)

These two values, M and D, have no definite relation to each other, and the answer to the question whether M is greater than D or D than M will depend on the value which is inserted for p, the rate of discount. If p is small M will be large; if p is large M will be small. But if M is larger than D it follows that forest management is more profitable than devastation, since it is the system which makes the capital value of the forest greater. And if D is larger than M, devastation is more profitable than forest management. Thus the financial choice between the two systems is dependent on the rate of discount which is adopted, and in each case there is a rate of discount above which devastation becomes more attractive than forest management.

In forests which are not already normal these simple formulae do not apply. In a forest which is entirely composed of mature, or over-mature, stands, e.g. an untouched, virgin forest, the choice generally lies between cutting the whole in the shortest possible time (devastation), or felling gradually over a rotation period—say, eighty years—and regenerating each area as it is felled (forest management). It may be assumed for the sake of comparison that

[1] Cf. p. 132.

under a system of devastation it is possible to fell the whole in one year. In this case the economic choice between the two systems is more complex and two major considerations are involved.

Under sustained yield management:

(i) Only a small portion of the forest is cut in the first year; the remainder is cut gradually, and some of it not till eighty years hence, if eighty years is the rotation period. The values of these future yields must therefore be discounted from the time when they will be cut to the present in order that they may be compared with the devastation values. If the volume or quality of the timber is still improving this will provide some compensation for the delay in felling, and if prices of timber are rising this will provide an additional compensation; but, unless these increments represent a rate per cent. which is as high as the rate of discount, some net loss is ncurred by this postponement of felling.

(ii) Each area is regenerated as it is felled, and has subsequently to be managed and protected, and taxes have frequently to be paid. The sums spent on these activities are a form of investment, and the financial attractiveness of this investment will depend on the rate of interest it can earn, i.e. on the *financial yield* of the stands which are initiated. If sufficient data are available this financial yield can be calculated in the manner shown in Chapter IX.

If the choice between the two systems, devastation and forest management, is made purely on direct financial grounds it will resolve itself into estimating the two rates of interest in paragraphs (i) and (ii) above, which may be called the value increment per cent. and the financial yield, and deciding whether these rates are sufficiently attractive to warrant conservative management. In both these cases, then, the normal forest and the virgin forest, the choice between devastation and forest management reduces itself to a choice between realizing a capital value or accepting an income spread over a great number of years. If no other considerations are taken into account the course chosen will be determined by the rate of interest which the possible income represents on the capital which might have been realized. If this rate of interest is low a financially minded forest owner will prefer devastation; if it is high he will prefer forest management. Outside a few European countries devastation is common and forest management is rare, and the chief reason for this is that the income from forest management generally represents a very low rate of interest on the capital invested in a forest.

In many cases, however, forest owners may expect to derive other

benefits from forest management, and the market value of the timber is not the only factor that must be taken into account, such other factors are discussed on pp. 230–3.

In actual practice forests are neither ideally normal nor entirely composed of mature or over-mature stands. The maturity and size of timber varies from place to place, and these variations will be utilized by a forest manager in order to introduce an approach to normality. But the reasons which may lead to a choice between devastation and forest management are the same in such mixed forests as in the extreme cases discussed above.

The conflict between public good and private gain. Despite the fact that some of the most intensive forest management in the world is to be found on private estates it may be accepted as a generalization that private or commercial ownership of forests, when unfettered by legislative restriction, generally leads to devastation. If land is required for agriculture or other productive purpose this is, of course, defensible and, in this sense, the agriculture of western Europe is built up on devastated forests. Further, in new countries the felling of timber may supply the wealth which is necessary for development, and in some of the western states of America forest devastation is not only yielding private profit but, through the medium of taxation, has been made to pay the greater part of the cost of roads, schools, and other public developments. Nevertheless, under a system of devastation forests are a wasting asset, and unless the land is used for other constructive purposes the prosperity of a country, and especially its timber supply, will be better assured by the introduction of forest management than by devastation. In many places, as in the countries of southern Europe, forest devastation has also led to soil erosion, water shortage, and other harmful effects.

Thus it frequently happens that the public interest requires sustained forest management, whereas the desire for private gain leads to devastation; and this conflict is one of the major issues with which the students of *forest policy* are concerned. The accepted solution of the problem is some form of state intervention, and state control of forests is now practised in nearly every civilized country in the world.

State control of forests. State control is exercised in various forms of which the most usual are,

(i) state ownership of forests;

(ii) legislation which controls the management of privately owned forests;

(iii) state control of forest owning companies through the ownership of a dominant share of the capital.

The relative advantages and disadvantages of these methods are a matter for students of forest policy, but they may be very briefly indicated here.

(i) State ownership is now found in most civilized countries and it is almost universally the case that state-owned forests are better managed than those in private hands. State ownership gives occasion for a forest service, and the training of state foresters has necessitated the founding of forest schools which have greatly advanced forest science. Further, ownership of state forests leads to continuity of policy. The dangers of state forestry are those associated with all forms of state managed industry, viz. over-centralization and the suppression of initiative in the junior members of the service; incidentally, the neglect of forest economics may be attributed to the absence of inducements to make state forests profitable. State forestry, however, labours under a special disadvantage which has received very little attention from writers on the subject. This handicap must be briefly discussed.

Timber is, for its value, a very bulky commodity and the cost of transporting it is high. When timber has been through a sawmill the sawn products represent about half the volume of the round timber and, being squared, they can be packed into less than half the space. Owing to drying their weight is much less than half the weight of the round logs. If timber is converted into pulp or paper the volume of the product is enormously less than that of the raw material. Consequently, it is necessary that sawmills and pulp mills should be so placed that transport costs will be reduced to a minimum, and forest owners are to some extent at the mercy of companies which are favourably placed for using their timber. Also, in order to secure efficient utilization very close co-operation is desirable between the management of forests and the management of those mills which use the timber. For these reasons a forest owner is in the strongest position when he can utilize his own timber so that the forests are run in direct co-ordination with sawmills and pulp-mills.

There is, however, in most countries, a very strong prejudice against the state entering into competition with industrial producers and, for this reason, forest services are actively discouraged from establishing their own mills. And, unless this disability can be overcome, state forestry will always be debarred from reaping the advantages that can be secured from combining the production

and utilization sides of the industry. But it may be noted that a few countries (e.g. Finland) own state sawmills and in Russia all the sawmills are owned by the government.

(ii) Legislative control over private forests has been introduced in many European countries, but nowhere in the British Empire or the U.S.A. Such legislative control aims at securing that all felled areas shall be regenerated and that subsequent management shall be reasonably efficient. The success of this method varies very much from country to country and depends on the energy with which the laws are administered. Such laws are unpopular with English-speaking peoples as they necessarily interfere with the liberty of the individual to do what he likes with his property; but, if other methods fail, it may be necessary to introduce such legislation.

(iii) The system of state controlled companies has not yet been tested very thoroughly, but it gives promise of very beneficial results. A company can own forests and mills and can work the two in conjunction, and if the state owns a dominating share of the capital it can insist, through its representatives, on the forests being managed on a sustained yield basis without otherwise restricting the commercial freedom or initiative of the organization. This system is at present in operation in the Gutzeit company in Finland.

Forest management under private ownership. In most countries the greater part of the forests is still privately owned, being in the possession either of private landowners or of lumbering companies. Small areas belong to communes, towns, and villages, and in countries, such as Germany, where the state maintains a certain amount of control over communal forests, they provide a considerable part of the revenue which has otherwise to be raised through rates. Forests may also be owned by ecclesiastical authorities and may then be under the protection of the state; in Finland the ecclesiastical forests are more conservatively managed than any others. In Europe, however, the chief area of forest is owned by individuals and the percentage of such ownership in various countries is shown in Table LVIII.

The areas belonging to individual owners are often very small. Thus in Germany eight million acres, or 9 per cent. of the total forests of the country, are owned in lots of less than 250 acres each. Such small ownership naturally leads to irregular and inefficient management. On some large hereditary estates, however, such as occur in Czechoslovakia, management may be extremely well

developed, and some of the best forest management in the world is found on such estates.

TABLE LVIII. *Percentage of forest in private ownership in certain countries (pre-war). (From Zon and Sparhawk.)*

	%		%
Austria	64·4	Great Britain and Ireland [1]	96·4
Czechoslovakia	63·9	Norway	79·0
Finland	64·9	Poland	69·6
France	65·5	Sweden	76·4
Germany	47·3	U.S.A.	79·1
Canada	6·7		

The ownership of forests by lumbering companies is rarely found in Europe, though nearly 5 million acres are owned in this manner in Finland and about 4 million acres in Sweden. In North America, however, this form of ownership is far more common, and the chief problem of American forest policy is to induce companies which own forests to manage them on a sustained yield basis. The problems of forest management under companies are more directly economic than those of individually owned forests.

Company forest management. In most of the forests of North America the devastation value of a forest is greater than the management value, and this is the principal factor which leads to devastation. If a company which owns a tract of forest finds that it can better serve its interests by erecting a temporary sawmill and converting all the timber as rapidly as possible than by instituting a system of conservative management, it is not likely to be greatly influenced by such considerations as the public benefit which would accrue from a system of sustained yield. There are, however, certain factors which tend to counteract this tendency towards devastation, of which the principal are the following.

(1) When timber is converted in temporary sawmills not much capital is sunk in machinery and buildings. When the area is worked out the more valuable parts of a mill can be removed, and the cost of erection has to be regarded in the light of a wasting asset the loss on which must be met by a depreciation fund. But the larger and more elaborate sawmills become the greater will be the loss in removal and the greater will be the inducement to keep them in the same position. Removal, however, will sooner or later become necessary unless the area which supplies them with timber

[1] By 1928, owing to the plantations made by the Forestry Commission, the percentage of privately owned forests in Britain had fallen to 88·3.

is continuously productive, and this can ultimately only be secured by a system of sustained yield.

This inducement towards conservative management becomes much more effective in the case of pulp and paper companies. Large pulp and paper factories are very expensive indeed and, as they have to be erected in suitable positions for pulpwood supply, many of the more important companies have had to build towns to accommodate their workpeople. Any shortage of timber in the areas from which they derive their supplies would thus be a cause of very serious loss to such companies. For this reason the pulp and paper manufacturers of eastern Canada are already giving serious consideration to methods of ensuring their future supplies.

(2) The timber trade of America has been built up on large-sized timber; but, as local shortage has become acute, it has become necessary to utilize smaller and smaller sizes, and a good deal of the American industry is now maintained on 'second growth' timber, the outcome of sporadic regeneration which has occurred as a result of fellings made many years ago. In the southern states, where pitch pine has been the principal timber produced, many companies have gone out of existence through lack of raw material, and the second growth is often worked by small, temporary mills; but a few of the larger companies have been able to buy up extensive areas of second growth and to continue their profitable existence by this means. If they can carry on in this manner until the second growth on their original areas is fit for cutting, a form of sustained-yield management may arise, and it will be profitable to encourage regeneration and to nurse regenerated areas.

Foresters will recognize in this the natural evolution of forest management and, were it not for the disastrous frequency of forest fires on cut-over areas, this kind of development might be expected to lead to the stabilization of timber production in America. It presupposes, however, the existence of well-established firms which can afford to look a long way into the future and to spend money on securing continuity, money which will bring no direct return for many years. To make use of second growth which has come without human effort involves no great financial strain, but to start a forest service and to invest money in order to obtain better and more regular regeneration and protection requires an understanding of forestry economics and a belief that such investments will yield satisfactory returns.

(3) Small trees cost more per cubic foot to fell and transport to the

mill than large trees, and are worth less when they reach the mill. The relation of these costs to size has been worked out by Ashe[1] in America, and the extent to which costs decrease with increased size has been found to be greater than was generally realized. There must, therefore, be a minimum size below which it does not pay to cut trees. If all trees below a certain diameter limit are left until the area can be cut over twenty or thirty years later, when again the small trees are left, a selection system of forest management may be gradually evolved. This line of development has been considered in a favourable light by Kirkland, but it must be remembered that the use of the diameter limit in securing sustained yield has not been found effective in North America and the selection system is one of the most difficult to organize effectively.

(4) In any forest tract which a company controls the trees which are situated near the mill or in parts where extraction is easy have a far higher *standing* value than those at a distance or where extraction is difficult. There will generally be some areas in which the cost of extraction is so high that the standing value is nil, and others in which it is very slight. Let us suppose that the value in the round at the mill is 1*s.* per cubic foot and that the cost of felling and extraction in favourable situations is 4*d.* and in unfavourable situations 11*d.* Then the standing value in the former situation will be 8*d.*, and in the latter 1*d.*, per cubic foot. If during the next few years the market price of lumber rises so that the value of round timber at the mill is raised to 1*s.* 2*d.* then the corresponding standing prices are raised to 10*d.* and 3*d.* respectively, a rise of 25 per cent. in the first case and 200 per cent. in the second. On the whole lumber prices are rising from decade to decade, especially in America, so that, despite occasional slumps, such rises may be anticipated. It may thus be to the interest of large lumbering companies to leave some areas of timber standing rather than to fell them. On this basis Kirkland[2] has propounded a scheme of sustained yield which might be in the economic interest of a lumbering company.

It is a hopeful sign that these tendencies towards sustained-yield management can be found in America, but it must be admitted that the devastation which is described on pp. 9–11 is still continuing. The difficulties which face the lumbering companies are discussed

[1] W. W. Ashe, 'Adjustment of the volume removed in selection felling', *Journ. of Forestry*, xxiv, 1926, p. 862. For a more detailed study see A. Specht, *Forstarchiv*, iv, 1928, p. 341.

[2] B. P. Kirkland, 'Flexible Rotation in American Forest Organisation', *Journ. of Forestry*, xxiii, 1925.

by Mason.[1] The large mills would require very extensive areas of forest to keep them continuously supplied, and most mills buy timber from the state or other owners, as well as cutting their own forests. In Finland[2] the larger companies tend to use first the timber which they can buy and to reserve their own forests against a period of shortage or high prices, and in this way they may fell less than the increment in their own forests over considerable periods. This method is utilized by Messrs. Frisch, Pruyn & Co., of New York State,[3] in order to get their own forests into a state of sustained yield, since it has been found necessary to cut less than the increment for some years.

Rate of profit is the controlling factor. Private or company ownership can only be expected to ensure adequate supplies of timber if the maintenance of forests yields a satisfactory rate of interest on the capital invested in the industry, or if some method of compulsion is exercised by governments. It is, therefore, very important that all possible measures should be adopted to reduce the costs of production and to enhance the value of the products. This is the fundamental aim of forest economics.

The form of expression which is most directly useful in relation to costs is the cost of production. In chapter XII the cost of production of various species at various sizes in Britain has been estimated; and such costs of production are based on an average set of figures representing price of land, cost of planting, and cost of annual management. If these can be cheapened, or if the rate of growth can be accelerated, the cost of production can be lowered.

The following are factors which make for cheap cultivation of timber trees:

(i) rapid growth;
(ii) cheap land;
(iii) cheap initiation, whether by natural or artificial regeneration;
(iv) cheap management and protection;
(v) satisfactory sale for intermediate products, especially thinnings.

Where all these favourable factors are present the cost of production may be very low. In Britain the cheapest timbers to grow are Douglas fir and Sitka spruce because they are rapid in growth, and Douglas fir yields saleable thinnings from quite early in the

[1] D. T. Mason, 'Sustained Yield and American Forest Problems', *Journ. of Forestry*, xxv, 1927, p. 625.

[2] Hiley, 'The Forest Industry of Finland', *Oxf. For. Memoir*, No. 8, 1928.

[3] H. L. Churchill, 'An example of industrial forestry in the Adirondacks', *Journ. of Forestry*, xxvii, 1929, p. 23.

rotation. The fact that Scots pine costs far more to grow than Douglas fir, although it grows on cheaper land and is cheaper to plant, suggests that rate of growth has a greater influence on the cost of production than the cost of land or planting.

One of the cheapest timbers to grow is the redwood, *Sequoia sempervirens*, in California. This tree regenerates very freely, partly from root-suckers, and partly from seed, and the mean annual volume increment is very high.[1] If fire can be kept out maintenance need not be expensive. For these reasons the redwood forests are more likely to be maintained by private enterprise than any other forests in western America.

Timber of slowly growing trees can only be cultivated cheaply if other factors are very favourable. Thus in south Finland Scots pine grows no faster than in Britain, but the cost of initiation by means of direct seeding is only 14*s*. per acre and the cost of management is about 10*d*. per acre per annum, and trees of 13 c.f. can be grown at a cost price of about 5½*d*. per cubic foot, and yield 5 per cent. interest on invested capital.[2]

One of the chief deterrents to forest management in America, and particularly in the western states, is the high taxation on forests. This taxation takes the form of a property tax on the value of the forests and an income tax on the annual proceeds of felling it. A high property tax is a direct inducement to rapid felling, and many loggers would rather become dispossessed of the land which they have cut over than pay the taxes which are levied on such areas. Indeed, over one million acres of cut-over land in Oregon alone are now abandoned and tax delinquent.[3] An income or yield tax is not an incentive to devastation and is therefore much less harmful to forest management than a property tax which may have to be paid for many years on land from which no income is derived. But to the taxing authorities a property tax is preferable to a yield tax because it yields a more regular income.[4]

The profitableness of forestry depends on the relation between the cost of production and the sale price of timber; and the sale price of standing timber depends on many factors such as species, size,

[1] Probably the highest for any conifer in the world. In the yield tables compiled by D. Bruce (*Cal. Agric. Exp. Sta. Bull.*, No. 361, 1923) Quality I shows a standing volume of 20,200 c.f. at 60 years, and Quality III, 14,400 c.f.

[2] Hiley, *Oxf. For. Memoir*, No. 8, 1928.

[3] Sinclair A. Wilson, 'Some economic aspects of forestry from a banker's standpoint', *Journ. of Forestry*, xxvii, 1929, p. 38.

[4] The subject of forest taxation is discussed in detail in H. H. Chapman's *Forest Finance*. See also Wilson, *supra*.

quality, distance from mill, and distance from market. Timber in a forest from which extraction is easy is worth more than similar timber growing in a region which is difficult of access. Consequently if other conditions are the same, forestry is most profitable where extraction is cheapest. But in such places land is generally more highly priced, and the economic forester must be prepared to estimate how much it is worth while to pay for well-situated land.

The price of standing timber also varies very much from country to country, and is generally highest in those countries which are the least provided with forests. For this reason there is some truth in the generalization that forestry only pays in regions where there are no forests. The southern hemisphere is notably deficient in conifers and, consequently, such good markets can be found, even for inferior softwoods, that companies can be floated with the sole object of planting up bare ground, as is done in New Zealand, Australia and, to some extent, in South Africa. In the U.S.A. prices vary very much according to region and are naturally highest where the demand for sawn timber is greatest. Boyce[1] states that the average price per thousand board feet of second growth softwoods is \$8·77 in New England, \$8·14 in the Middle Atlantic States, \$5·26 in the South Atlantic States, \$3·58 in the lower Mississippi Valley, \$3·07 in the Lake States, and \$1·82 in the Pacific North-west. The average price in the Pacific North-west is therefore only about ½*d.* per cubic foot which should be compared with about 5*d.* in South Finland, 6*d.* to 1*s.* in Britain, and about 1*s.* in South Africa. It is clear from this that industrial forestry is difficult in the Pacific North-west, despite the fact that this is a region of very rapid growth.

[1] Chas. W. Boyce, 'Forestry—a business', *Journ. of Forestry*, xxvii, 1929, p. 27.

APPENDIX I

Compound Interest Table (Future value of £1 at *n* years compound interest.)

Rate of interest per cent.

n (*years.*)	1%	2%	3%	4%
1	1·010	1·020	1·030	1·040
2	1·020	1·040	1·061	1·086
3	1·030	1·061	1·093	1·125
4	1·040	1·082	1·125	1·170
5	1·051	1·104	1·159	1·217
6	1·061	1·126	1·194	1·265
7	1·072	1·149	1·230	1·316
8	1·083	1·172	1·267	1·369
9	1·094	1·195	1·305	1·423
10	1·105	1·219	1·344	1·480
11	1·116	1·243	1·384	1·539
12	1·127	1·268	1·426	1·601
13	1·138	1·294	1·468	1·665
14	1·149	1·319	1·513	1·731
15	1·161	1·346	1·558	1·801
16	1·173	1·373	1·605	1·873
17	1·184	1·400	1·653	1·948
18	1·196	1·428	1·702	2·026
19	1·208	1·457	1·753	2·107
20	1·220	1·486	1·806	2·191
25	1·282	1·641	2·094	2·666
30	1·348	1·811	2·427	3·243
35	1·417	2·000	2·814	3·946
40	1·489	2·208	3·262	4·801
45	1·565	2·438	3·782	5·841
50	1·645	2·692	4·384	7·107
55	1·728	2·972	5·082	8·646
60	1·817	3·281	5·892	10·520
65	1·909	3·622	6·830	12·799
70	2·007	3·999	7·918	15·572
75	2·109	4·416	9·179	18·945
80	2·217	4·875	10·641	23·050
85	2·330	5·383	12·336	28·044
90	2·448	5·943	14·300	34·199
95	2·573	6·562	16·578	41·511
100	2·705	7·245	19·219	50·505
110	2·987	8·831	25·828	74·760
120	3·300	10·765	34·711	110·663
130	3·645	13·123	46·649	163·808
140	4·268	15·996	62·692	242·475
150	4·796	19·500	84·253	358·923
200	7·316	52·485	369·356	2550·750

Rate of interest per cent.

n (*years.*)	5%	6%	8%	10%
1	1·050	1·060	1·080	1·100
2	1·102	1·124	1·166	1·210
3	1·158	1·191	1·260	1·331
4	1·215	1·262	1·360	1·464
5	1·276	1·338	1·469	1·610
6	1·340	1·418	1·587	1·772
7	1·407	1·504	1·714	1·949
8	1·477	1·594	1·851	2·144
9	1·551	1·689	1·999	2·358
10	1·629	1·791	2·159	2·594
11	1·710	1·898	2·332	2·853
12	1·796	2·012	2·518	3·138
13	1·886	2·133	2·720	3·452
14	1·980	2·261	2·937	3·798
15	2·079	2·397	3·172	4·177
16	2·183	2·540	3·426	4·595
17	2·292	2·693	3·700	5·054
18	2·407	2·854	3·996	5·560
19	2·527	3·026	4·316	6·116
20	2·653	3·207	4·661	6·728
25	3·386	4·291	6·849	10·835
30	4·322	5·743	10·063	17·450
35	5·516	7·686	14·785	28·103
40	7·040	10·286	21·725	45·260
45	8·985	13·765	31·921	72·893
50	11·467	18·420	46·903	117·393
55	14·636	24·651	68·916	189·067
60	18·679	32·988	101·260	304·494
65	23·840	44·146	148·785	490·393
70	30·426	59·077	218·615	789·788
75	38·833	79·059	321·218	1271·965
80	49·561	105·798	471·976	2048·519
85	63·254	141·529	693·489	3299·174
90	80·730	189·470	1018·965	5313·366
95	103·035	253·554	1497·199	8557·255
100	131·501	339·312	2199·884	13781·614
110	214·382	607·659	4749·413	35746·198
120	348·912	1088·228	10253·679	92717·021
130	568·341	—	—	—
140	925·767	—	—	—
150	1507·977	—	—	—
200	17292·581	—	—	—

APPENDIX II

Yield Tables from British, Continental and American Sources.

The following tables are quoted from Forestry Commission Bulletin No. 10, 1928. Volumes of mean annual increment have been added.

Scots pine (England) (3 qualities)	Qualities	I, II, III.
European larch (5 qualities)	„	I, III, V.
Norway spruce (5 qualities)	„	I, III, V.
Douglas fir (4 qualities)	„	I, III, IV.
Corsican pine (3 qualities)	Quality	I.

The quality classes of these tables are also designated by the mean height attained in 50 years.

In these tables the measurements of basal areas and volumes are quarter girth, under bark, per acre. For conversion to true measure these figures must be multiplied by 1·273.

For converting British units, quarter girth, to metric units, true measure, the following factors may be used.

1 foot = 0·3048 metre.
1 square foot = 0·09290 square metre.
1 cubic foot = 0·02832 cubic metre.

Number of stems per acre × 2·471 = number of stems per hectare.
Square feet, per acre, q.g. × 0·2922 = square metres per hectare.
Cubic feet per acre, q.g. × 0·0891 = cubic metres per hectare.

The yield table for Oak is converted from Schwappach (*Untersuchungen über die Zuwachsleistungen von Eichen-Hochwaldbeständen in Preussen*, Neudamm, 1905). Schwappach's table has three quality classes of which Classes I and III have been converted. Basal areas and volumes have been converted to British units, true measure. The thinning period has been altered from 5 years to 10 years.

The yield table for Redwood (*Sequoia sempervirens*) is quoted from Donald Bruce (University of California, *Agr. Exp. Stat. Bull.* No. 361, 1923), and was estimated from measurements of second-growth stands. No figures for thinnings are available. The figures for volumes are true measure, and include the whole stem, under bark.

For converting from true measure to quarter girth measure, the figures for basal area and volume should be multiplied by 0·785.

Square feet per acre true measure × 0·2296 = square metres per hectare.
Cubic feet „ „ „ × 0·0700 = cubic metres per hectare.

SCOTS PINE—England

Age. years.	Main Crop. Mean Height. ft.	Mean Quarter Girth. ins.	No. of stems.	Basal Area. sq.ft.	Form Factor.	Vol. cub.ft.	Thinnings. No. of stems.	Vol. cub.ft.	Mean annual increment. Volume. cub.ft.
Quality Class I (60 ft.)									
25	33	3¾	1,010	91	·370	1,110	—	—	44
30	40	4½	810	113	·383	1,730	—	—	56
35	46	5¼	655	129	·383	2,280	155	135	69
40	51	6¼	545	141	·380	2,730	110	170	76
45	56	7	445	150	·377	3,170	100	195	82
50	60	7¾	375	156	·377	3,530	70	210	85
55	64	8½	325	162	·375	3,890	50	210	87
60	67	9	285	165	·376	4,160	40	225	88
65	70	9¾	255	169	·374	4,430	30	220	89
70	72½	10¼	230	171	·374	4,640	25	220	89
75	75	11	210	174	·373	4,870	20	210	89
80	77	11½	193	176	·373	5,050	17	200	88
85	79	12	179	179	·372	5,230	14	190	87
90	81	12½	167	180	·371	5,410	12	180	86
95	83	13	157	182	·370	5,590	10	170	85
100	84½	13¼	150	183	·370	5,730	7	160	84
Quality Class II (50 ft.)									
30	31	3¾	1,040	93	·392	1,130	—	—	38
35	36½	4½	835	113	·400	1,650	—	—	47
40	41½	5¼	680	128	·397	2,110	155	120	56
45	46	6	570	140	·391	2,520	110	140	62
50	50	6¾	480	149	·388	2,890	90	150	66
55	54	7½	405	157	·386	3,270	75	160	70
60	57	8	350	161	·386	3,550	55	170	72
65	60	8¾	305	165	·386	3,820	45	175	73
70	62½	9½	270	169	·384	4,060	35	180	74
75	65	10	245	172	·384	4,300	25	180	74
80	67	10½	225	173	·385	4,470	20	175	74
85	69	11	207	176	·385	4,670	18	165	74
90	71	11½	192	177	·386	4,850	15	155	74
95	73	12	179	179	·385	5,030	13	145	73
100	74	12¼	170	180	·385	5,130	9	130	72

Age. years.	Main Crop. Mean Height. ft.	Mean Quarter Girth. ins.	No. of stems.	Basal Area. sq.ft.	Form Factor.	Vol. cub.ft.	Thinnings. No. of stems.	Vol. cub.ft.	Mean annual increment. Volume. cub.ft.
				Quality Class III (40 ft.)					
35	28½	3½	1,060	93	·392	1,040	—	—	30
40	32½	4¼	885	108	·410	1,440	—	—	36
45	36½	5	720	123	·410	1,840	170	85	43
50	40	5¾	610	134	·408	2,190	110	95	47
55	43	6¼	520	142	·408	2,490	90	105	51
60	46	7	445	150	·404	2,790	75	115	53
65	49	7½	385	156	·404	3,090	60	120	55
70	51	8¼	345	160	·403	3,290	40	130	56
75	53	8¾	310	163	·404	3,490	35	130	57
80	55	9¼	280	166	·403	3,680	30	130	57
85	57	9¾	253	169	·404	3,890	27	130	58
90	59	10¼	230	171	·404	4,080	23	125	58
95	61	10¾	212	174	·404	4,280	18	115	58
100	62	11¼	200	175	·405	4,390	12	105	58

Age. years.	Main Crop. Mean Height. ft.	Mean Quarter Girth. ins.	No. of stems.	Basal Area. sq. ft.	Form Factor.	Volume. cub. ft.	Thinnings. No. of stems.	Volume. cub. ft.	Mean annual increment. Volume. cub. ft.
EUROPEAN LARCH									
Quality Class I (80 ft.)									
20	40	4	900	98	·398	1,560	—	—	78
25	50	5	670	114	·403	2,300	230	155	98
30	58	6	520	126	·397	2,900	150	190	108
35	65	6¾	420	134	·394	3,430	100	220	114
40	71	7½	350	140	·390	3,880	70	245	117
45	76	8¼	295	144	·389	4,260	55	270	118
50	80	9	260	148	·386	4,570	35	290	119
55	84	9¾	230	151	·384	4,870	30	315	119
60	87½	10¼	205	153	·383	5,130	25	330	119
65	91	10¾	185	155	·383	5,400	20	325	119
70	94	11½	170	157	·382	5,630	15	290	118
75	97	12	158	158	·382	5,850	12	250	116
80	100	12¼	150	159	·382	6,070	8	210	114
Quality Class III (60 ft.)									
25	33	3½	1,060	87	·352	1,010	—	—	40
30	39½	4¼	800	100	·370	1,460	—	—	49
35	45½	5	620	111	·374	1,890	180	145	58
40	51	5¾	510	119	·377	2,290	110	160	65
45	56	6½	430	126	·374	2,640	80	175	69
50	60	7¼	370	132	·367	2,910	60	185	72
55	64	7¾	325	137	·365	3,200	45	195	74
60	67½	8½	285	141	·362	3,440	40	205	75
65	71	9	250	144	·362	3,700	35	215	77
70	74	9¾	220	147	·359	3,910	30	215	77
75	77	10½	200	150	·358	4,130	20	200	78
80	79½	11	185	152	·356	4,300	15	160	77
Quality Class V (40 ft.)									
40	32	3½	1,010	87	·338	940	—	—	23
45	36	4¼	790	97	·344	1,200	220	75	28
50	40	5	620	105	·348	1,460	170	90	32
55	44	5¾	500	113	·346	1,720	120	100	36
60	47½	6¼	425	119	·343	1,940	75	115	39
65	50½	7	365	123	·343	2,130	60	125	41
70	53½	7½	320	128	·340	2,330	45	140	43
75	56½	8¼	280	132	·339	2,530	40	145	44
80	59	8¾	250	136	·335	2,690	30	140	45

Age. years.	Main Crop. Mean Height. ft.	Mean Quarter Girth. ins.	No. of stems.	Basal Area. sq.ft.	Form Factor.	Volume. cub.ft.	Thinnings. No. of stems.	Volume. cub.ft.	Mean annual increment. Volume. cub.ft.
				NORWAY SPRUCE					
				Quality Class I (80 *ft.*)					
25	41	4½	1,080	152	·385	2,400	—	—	96
30	51	5¾	710	171	·401	3,500	370	410	130
35	59	7	535	183	·407	4,400	175	440	150
40	66½	8¼	410	194	·407	5,250	125	485	165
45	73½	9½	335	203	·404	6,030	75	490	175
50	80	10½	280	211	·401	6,760	55	470	181
55	86	11½	240	217	·398	7,420	40	445	185
60	91	12½	210	223	·395	8,020	30	415	186
65	96	13¼	190	228	·391	8,530	20	345	185
70	100	14	175	231	·388	8,960	15	320	183
				Quality Class III (60 *ft.*)					
30	36½	4	1,310	146	·402	2,140	—	—	71
35	43	5	930	162	·422	2,950	380	180	90
40	49	6¼	665	177	·424	3,680	265	210	102
45	55	7¼	500	188	·420	4,360	165	240	111
50	60	8¼	410	198	·415	4,930	90	270	116
55	64	9¼	350	205	·414	5,440	60	280	120
60	68	10¼	300	212	·409	5,910	50	260	122
65	72	11	260	219	·402	6,340	40	240	123
70	75	11¾	230	224	·401	6,730	30	200	123
				Quality Class V (40 *ft.*)					
40	31	3½	1,500	130	·414	1,670	—	—	42
45	36	4½	1,020	148	·428	2,290	480	90	53
50	40	5½	765	162	·435	2,820	255	110	60
55	44	6½	615	173	·432	3,290	150	130	66
60	47½	7¼	500	183	·427	3,700	155	150	70
65	50½	8	430	191	·424	4,080	70	160	73
70	53	8¾	375	197	·422	4,400	55	155	74

Age. years.	Main Crop. Mean Height. ft.	Main Crop. Mean Quarter Girth. ins.	Main Crop. No. of stems.	Main Crop. Basal Area. sq. ft.	Main Crop. Form Factor	Main Crop. Volume. cub. ft.	Thinnings. No. of stems.	Thinnings. Volume. cub. ft.	Mean annual increment. Volume. cub. ft.
				DOUGLAS FIR					
				Quality Class I (110 ft.)					
15	38	3½	1,330	115	·384	1,680	—	—	112
20	53½	5½	715	150	·375	3,010	615	430	172
25	67	7¼	470	173	·360	4,170	245	590	207
30	78	9	335	190	·346	5,130	135	625	225
35	87	10¾	255	201	·339	5,930	80	640	235
40	95½	12¼	205	211	·329	6,630	50	595	238
45	103	13¾	170	219	·323	7,290	35	570	239
50	110	15¼	140	225	·319	7,900	30	540	237
				Quality Class III (90 ft.)					
20	39½	4	1,115	126	·398	1,980	—	—	99
25	51	5¾	650	155	·376	2,970	465	305	131
30	60½	7½	445	174	·363	3,820	205	420	151
35	69	9	335	188	·352	4,570	110	440	164
40	76½	10½	265	199	·344	5,240	70	450	171
45	83½	12	210	208	·337	5·850	55	485	177
50	90	13¼	170	216	·330	6,420	40	465	180
				Quality Class IV (80 ft.)					
20	33½	3¼	1,530	111	·403	1,500	—	—	75
25	43	4¾	860	138	·403	2,390	670	200	104
30	52	6½	570	164	·375	3·200	290	305	123
35	60	8	415	180	·364	3,930	155	355	137
40	67½	9½	310	193	·352	4,590	105	390	146
45	74	11	245	203	·346	5,190	65	410	152
50	80	12¼	200	210	·342	5,740	45	405	156
				CORSICAN PINE					
				Quality Class I (70 ft.)					
20	29	3¼	1,630	122	·350	1,240	—	—	62
25	37½	4¼	1,095	139	·386	2,010	535	135	86
30	45	5½	740	152	·398	2,720	355	195	102
35	52	6½	555	162	·400	3,370	185	235	112
40	58½	7½	435	171	·397	3,970	120	265	120
45	64½	8½	355	179	·392	4,530	80	285	125
50	70	9½	295	185	·390	5,050	60	300	129

Age. years.	Main Crop. Mean Height. ft.	Mean Diam. ins.	No. of Stems. per acre.	Basal area (true measure). sq.ft. per acre.	Form factor.	Volume (true measure) cub.ft. per acre.	Thinnings. No. of Stems. per acre.	Volume cub.ft. per acre.	Mean annual increm't (true measure) cub.ft. per acre.
				OAK (after Schwappach, Prussia)					
				Quality Class I					
20	25	1·7	3,060	46	·335	370	—	—	18
30	37	2·8	1,430	63	·422	970	1,630	340	44
40	48	4·4	710	75	·480	1,730	720	690	69
50	58	6·3	393	86	·506	2,530	317	830	88
60	67	8·3	254	95	·517	3,280	139	900	101
70	74	10·2	180	104	·521	3,970	74	900	109
80	79	12·2	137	111	·524	4,600	43	830	114
90	83	14·0	110	117	·526	5,160	27	710	115
100	87	15·7	92	123	·527	5,670	18	610	115
110	91	17·2	80	129	·528	6,160	12	560	114
120	94	18·6	71	133	·530	6,600	9	500	112
130	97	19·8	64	136	·532	6,970	7	460	110
140	99	20·8	59	138	·533	7,310	5	460	108
150	102	21·8	55	141	·534	7,650	4	460	106
160	104	22·7	51	143	·534	7,960	4	460	104
170	106	23·6	48	145	·536	8,220	3	460	103
180	108	24·4	45	145	·537	8,430	3	460	101
190	110	25·0	42	145	·538	8,600	3	440	99
200	112	25·6	40	145	·539	8,720	2	430	97
				Quality Class III					
30	16	1·4	4,520	52	·210	170	—	—	6
40	23	2·3	2,140	64	·290	430	2,380	130	14
50	30	3·6	1,030	75	·357	790	1,110	390	26
60	36	5·0	617	84	·405	1,210	413	600	39
70	42	6·5	410	92	·448	1,740	207	700	51
80	48	7·9	294	99	·479	2,300	116	670	60
90	53	9·3	222	106	·499	2,800	72	530	65
100	57	10·5	182	111	·511	3,230	40	410	67
110	61	11·5	158	114	·513	3,560	24	360	67
120	64	12·5	138	117	·514	3,840	20	300	66
130	67	13·4	122	119	·514	4,100	16	270	65
140	70	14·2	109	120	·516	4,330	13	260	64
150	73	15·0	98	120	·518	4,530	11	260	63
160	75	15·8	89	120	·520	4,690	9	230	61
170	77	16·6	80	119	·522	4,810	9	230	60
180	79	17·3	73	119	·524	4·910	7	230	58
190	81	18·0	66	117	·527	4,990	7	200	57
200	82	18·7	61	116	·531	5,040	5	200	55

Age. years.	Mean Height. ft.	Average Diam. B.H. over bark ins.	Number of Stems. per acre.	Basal area (true measure) per acre, over bark sq. ft.	Volume (true measure) per acre, under bark cub. ft.	Mean annual increment (true measure main crop only), under bark cub. ft.
			REDWOOD (Sequoia sempervirens)			
			Quality Class I			
20	51	7·8	898	299	6,000	300
25	62	9·7	695	357	8,000	320
30	72	11·2	585	400	10,200	340
35	83	12·6	496	430	12,400	354
40	93	13·6	445	450	14,500	362
45	103	14·5	405	465	16,400	364
50	112	15·3	372	476	17,900	359
55	121	16·0	347	484	19,200	350
60	130	16·7	319	486	20,200	337
			Quality Class II			
20	43	7·2	980	278	5,100	255
25	53	8·9	765	331	6,800	272
30	61	10·4	628	372	8,700	290
35	71	11·6	543	399	10,600	303
40	79	12·5	489	418	12,400	309
45	87	13·3	447	431	13,900	310
50	95	14·1	406	441	15,300	305
55	103	14·7	374	449	16,300	297
60	110	15·4	348	451	17,100	286
			Quality Class III			
20	38	6·9	1,020	266	4,200	210
25	47	8·7	777	316	5,700	228
30	54	10·1	638	356	7,300	243
35	62	11·2	556	381	8,900	254
40	70	12·1	500	400	10,400	260
45	77	12·9	453	412	11,700	260
50	84	13·7	412	422	12,800	256
55	91	14·3	384	429	13,700	248
60	98	14·9	356	431	14,400	240

APPENDIX III

Multipliers for use with the Faustmann formula.

$$S = \frac{Y_r + \Sigma T_a \,.\, 1{\cdot}0p^{r-a} - C \,.\, 1{\cdot}0p^r}{1{\cdot}0p^r - 1} - \frac{e}{\cdot 0p}.$$

Where S = value of land.

Y_r = standing value of final yield.

T_a = standing value of thinning in year a.

T_b = standing value of thinning in year b (&c.).

C = Cost of planting.

e = cost of annual maintenance.
all values per unit area.

r = rotation.

p = rate of interest at which calculation is made.

This equation may be written:

$$S = Y_r \,.\left(\frac{1}{1{\cdot}0p^r - 1}\right) + T_a\left(\frac{1{\cdot}0p^{r-a}}{1{\cdot}0p^r - 1}\right) + T_b\left(\frac{1{\cdot}0p^{r-b}}{1{\cdot}0p^r - 1}\right) + \ldots - C\left(\frac{1{\cdot}0p^r}{1{\cdot}0p^r - 1}\right) - e\left(\frac{1}{\cdot 0p}\right).$$

For any given rotation and any given rate of interest (p) the amounts in brackets are constant and these amounts for rotations from 20 to 100 years can be read off from the following tables. The rates of interest given in the tables are 2, 3, 4, 5, 6, 7, 8, 10 for rotations from 20 to 60 years, and 1½, 2, 2½, 3, 4, 5, 6, 7 from 70 to 100 years, as these are the rates of interest which are found most useful in practical work.

On pp. 134–45 of this volume examples are given of the use of these tables.

Multipliers for calculation of soil expectation values and financial yields.

Rotation 20 *years*

Multiplier for.	2%	3%	4%	5%	6%	7%	8%	10%
Y20	2·0580	1·2405	·8396	·6049	·4531	·3485	·2731	·1746
T15	2·267	1·434	1·019	·772	·606	·488	·401	·281
C	3·06	2·24	1·84	1·60	1·45	1·35	1·27	1·17
e	50·0	33·3	25·0	20·0	16·7	14·3	12·5	10·0

Rotation 30 *years*

Y30	1·2330	·7008	·4458	·3010	·2108	·1512	·1103	·0608
T15	1·659	1·092	·803	·626	·505	·417	·350	·254
T20	1·503	·942	·660	·490	·378	·298	·238	·158
T25	1·361	·812	·543	·384	·282	·212	·162	·098
C	2·23	1·70	1·45	1·30	1·21	1·15	1·11	1·06
e	50·0	33·3	25·0	20·0	16·7	14·3	12·5	10·0

Rotation 40 *years*

Y40	·8278	·4421	·2631	·1656	·1077	·0716	·0483	·0226
T15	1·359	·926	·701	·561	·462	·388	·330	·245
T20	1·230	·798	·576	·439	·345	·277	·225	·152
T25	1·114	·689	·474	·344	·258	·197	·153	·094
T30	1·011	·594	·389	·270	·193	·141	·104	·059
T35	·914	·512	·320	·211	·144	·100	·071	·036
C	1·83	1·44	1·26	1·17	1·11	1·07	1·05	1·02
e	50·0	33·3	25·0	20·0	16·7	14·3	12·5	10·0

Rotation 50 *years*

Y50	·5910	·2955	·1638	·0955	·0574	·0351	·0218	·0086
T15	1·183	·832	·646	·527	·441	·375	·322	·241
T20	1·071	·717	·531	·413	·330	·267	·219	·150
T25	·970	·619	·437	·323	·246	·191	·149	·093
T30	·879	·534	·359	·253	·184	·136	·101	·058
T35	·796	·460	·295	·199	·138	·097	·069	·036
T40	·721	·397	·242	·156	·103	·069	·047	·022
T45	·653	·342	·199	·122	·077	·049	·032	·014
C	1·59	1·29	1·16	1·10	1·06	1·03	1·02	1·01
e	50·0	33·3	25·0	20·0	16·7	14·3	12·5	10·0

Rotation 60 *years*

Multi-plier for.	*2%*	*3%*	*4%*	*5%*	*6%*	*7%*	*8%*	*10%*
Y60	·4384	·2044	·1050	·0566	·0313	·0176	·0100	·0033
T15	1·069	·773	·613	·508	·430	·369	·318	·240
T20	·968	·667	·504	·398	·321	·263	·217	·149
T25	·877	·575	·414	·312	·240	·187	·147	·093
T30	·794	·496	·341	·244	·180	·134	·100	·057
T35	·719	·428	·282	·191	·134	·095	·068	·036
T40	·651	·369	·230	·150	·100	·068	·046	·022
T45	·590	·318	·189	·118	·075	·048	·032	·014
T50	·534	·275	·159	·092	·056	·034	·021	·008
T55	·484	·237	·128	·072	·042	·025	·015	·005
C	1·44	1·20	1·10	1·06	1·03	1·02	1·01	1·00
e	50·0	33·3	25·0	20·0	16·7	14·3	12·5	10·0

Rotation 70 *years*

	1½%	*2%*	*2½*	*3%*	*4%*	*5%*	*6%*	*7%*
Y70	·5450	·3334	·2159	·1446	·0686	·0340	·0172	·0089
T15	1·236	·991	·839	·735	·593	·498	·424	·366
T20	1·148	·897	·742	·634	·487	·390	·317	·261
T25	1·065	·813	·655	·547	·401	·305	·237	·186
T30	·989	·737	·579	·472	·330	·239	·177	·132
T35	·918	·667	·512	·407	·271	·187	·132	·094
T40	·852	·604	·453	·351	·222	·147	·099	·067
T45	·791	·547	·400	·303	·183	·115	·074	·048
T50	·734	·494	·354	·261	·150	·090	·055	·034
T55	·681	·448	·313	·225	·123	·071	·041	·024
T60	·632	·406	·276	·194	·101	·055	·031	·017
T65	·587	·368	·244	·168	·083	·043	·023	·013
C	1·545	1·334	1·216	1·145	1·069	1·035	1·016	1·009
e	66·6	50·0	40·0	33·3	25·0	20·0	16·7	14·3

Rotation 80 *years*

Y80	·4365	·2581	·1610	·1037	·0453	·0206	·0095	·0045
T15	1·149	·933	·800	·708	·579	·491	·421	·364
T20	1·066	·847	·708	·611	·477	·385	·315	·259
T25	·990	·767	·626	·527	·392	·301	·235	·185
T30	·919	·691	·553	·455	·322	·236	·176	·132
T35	·853	·628	·489	·392	·265	·185	·131	·094
T40	·792	·570	·432	·338	·218	·145	·098	·067
T45	·735	·515	·382	·292	·179	·114	·073	·048
T50	·682	·466	·338	·252	·147	·089	·055	·034
T55	·633	·422	·298	·217	·121	·070	·041	·024
T60	·588	·383	·264	·187	·099	·055	·031	·017
T70	·506	·314	·206	·140	·067	·033	·017	·009
C	1·436	1·255	1·161	1·104	1·045	1·020	1·009	1·004
e	66·6	50·0	40·0	33·3	25·0	20·0	16·7	14·3

Rotation 50 *years*

Multiplier for.	*1½%*	*2%*	*2½%*	*3%*	*4%*	*5%*	*6%*	*7%*
Y90	·3547	·2023	·1215	·0752	·0302	·0125	·0053	·0023
T15	1·083	·8933	·7743	·6902	·5720	·4870	·4194	·3629
T20	1·006	·8091	·6842	·5954	·4701	·3816	·3134	·2587
T25	·9337	·7328	·6047	·5136	·3864	·2989	·2342	·1845
T30	·8868	·6637	·5346	·4430	·3177	·2345	·1750	·1315
T35	·8044	·6012	·4725	·3821	·2610	·1835	·1308	·0938
T40	·7467	·5445	·4177	·3296	·2145	·1438	·0977	·0669
T45	·6933	·4932	·3691	·2844	·1764	·1127	·0730	·0477
T50	·6436	·4467	·3262	·2452	·1450	·0883	·0546	·0340
T55	·5973	·4046	·2883	·2115	·1191	·0692	·0408	·0242
T60	·5546	·3664	·2549	·1825	·0979	·0542	·0305	·0173
T70	·4777	·3006	·1991	·1358	·0661	·0333	·0170	·0088
T80	·4117	·2466	·1555	·1010	·0447	·0204	·0095	·0045
C	1·355	1·202	1·1215	1·075	1·030	1·012	1·005	1·002
e	66·6	50·0	40·0	33·3	25·0	20·0	16·7	14·3

Rotation 100 *years*

Y100	·2914	·1601	·0925	·0549	·0202	·0077	·0029	·0012
T15	1·033	·8620	·7546	·6760	·5665	·4848	·4184	·3629
T20	·9590	·7807	·6670	·5839	·4656	·3797	·3127	·2587
T25	·8900	·7071	·5893	·5037	·3827	·2976	·2336	·1845
T30	·8262	·6404	·5210	·4345	·3146	·2332	·1746	·1315
T35	·7670	·5801	·4605	·3748	·2585	·1827	·1305	·0938
T40	·7119	·5254	·4070	·3232	·2125	·1432	·0973	·0668
T45	·6609	·4758	·3597	·2789	·1747	·1121	·0729	·0477
T50	·6135	·4310	·3179	·2406	·1435	·0879	·0544	·0340
T55	·5696	·3904	·2809	·2075	·1180	·0688	·0407	·0242
T60	·5285	·3537	·2484	·1790	·0970	·0539	·0304	·0173
T70	·4555	·2900	·1940	·1332	·0655	·0331	·0170	·0088
T80	·3924	·2380	·1516	·0991	·0443	·0203	·0095	·0045
T90	·3382	·1952	·1184	·0737	·0299	·0125	·0053	·0023
C	1·291	1·160	1·092	1·055	1·020	1·008	1·003	1·001
e	66·6	50·0	40·0	33·3	25·0	20·0	16·7	14·3

INDEX

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